


TECHNICAL APPENDIX FORM (TA5031) FOR PRESSURE VESSELS
PRESSURE VESSEL ENGINEERING NOTE PER CHAPTER 5031

Prepared by: Terry Tope
Preparation date: 12.6.10

1. Description and Identification
Fill in the label information below:

THIS VESSEL CONFORMS TO FERMILAB ES&H MANUAL CHAPTER 5031	
Vessel Title	<u>LAPD Molecular Sieve Filter Vessel</u>
Vessel Number	<u>PPD10139</u>
Vessel Drawing No.	<u>Eden Cryogenics LLC BC-02128-5800-01</u>
Maximum Allowable Working Pressure (MAWP)	
Internal Pressure	<u>165 psid</u>
External Pressure	<u>15 psid</u>
Working Temperature Range	<u>+932 °F</u> °F <u>-320 °F</u> °F
Contents	<u>Liquid argon and Sigma Aldrich Molecular Sieve 4A</u>
Designer / Manufacturer	<u>Eden Cryogenics LLC</u>
Test Pressure (if tested at Fermilab)	Acceptance Date _____
_____ PSIG, Hydraulic _____	Pneumatic _____
Accepted as conforming to standard by	
<u></u>	
Of Division / Section	<u>PPD</u> Date: <u>8/15/11</u>

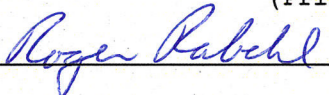
← Obtain from Division/Section Safety Officer

← Document per Chapter 5034 of the Fermilab ES&H Manual

← Actual signature required

NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review.

Reviewed by: ROGER RABEHL
(Print Name)

Signature:  Date: 3/21/11

Director's signature (or designee) if the vessel is for manned areas but doesn't conform to the requirements of the chapter.

Signature: _____ Date: _____

Fermilab ES&H Manual

TA 5031 - 1
Rev. 06/2009

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http://www-esh.fnal.gov/pls/default/esh_manuals.html

Amendment No.:

Reviewed by:

Date:

1

Roger Rabehl

10/15/12

Lab Property Number(s): n/a

Lab Location Code: 701030125 (obtain from safety officer)

Purpose of Vessel(s): Remove water from liquid argon.

Vessel Capacity/Size: 22.5 gallon Diameter: 12.75 inches Length: 51.5 inches

Normal Operating Pressure, (OP) 30 psid

MAWP-OP = 165 - 30 = 135 PSID

List the numbers of all pertinent drawings and the location of the originals.

Drawing #

Eden Cryogenics LLC BC-02128-5800-01

Location of Original

8445 Rausch Dr Plain City, OH 43064

Repair (Amendment No. 1):

Fermilab 3942.330-MD-489456

Fermi National Accelerator Laboratory

Fermilab 3942.330-MD-489458

2. Design Verification

Is this vessel designed and built to meet the ASME BPVC or "Experiment Vessel" requirements?

Yes X No

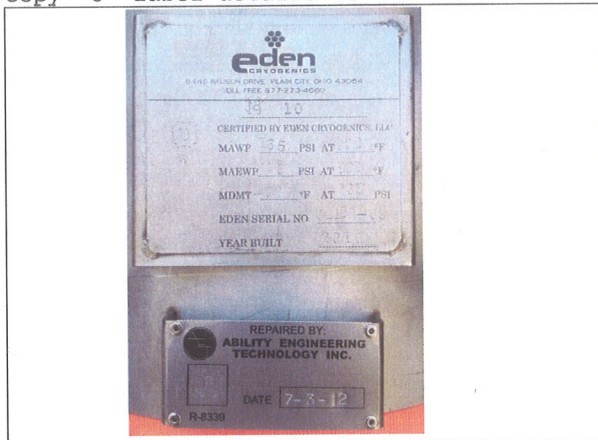
If "No" state the standard that was used

Demonstrate that design calculations of that standard have been made and that other requirements of that standard have been satisfied.
Skip to part 3 "system venting verification."

Does the vessel(s) have a U stamp? Yes X No . If "Yes", complete section 2A; if "No", complete section 2B.

A. Staple photo of U stamp plate below.

Copy "U" label details to the side



Copy data here:

NB 10

CERTIFIED BY EDEN CRYOGENICS LLC

MAWP 165 PSI AT 932 °F

MAEWP 15 PSI AT 932 °F

MDMT -320 °F at 165 PSI

EDEN SERIAL NO 02128-03

YEAR BUILT 2010

Fermilab ES&H Manual

TA 5031 - 2

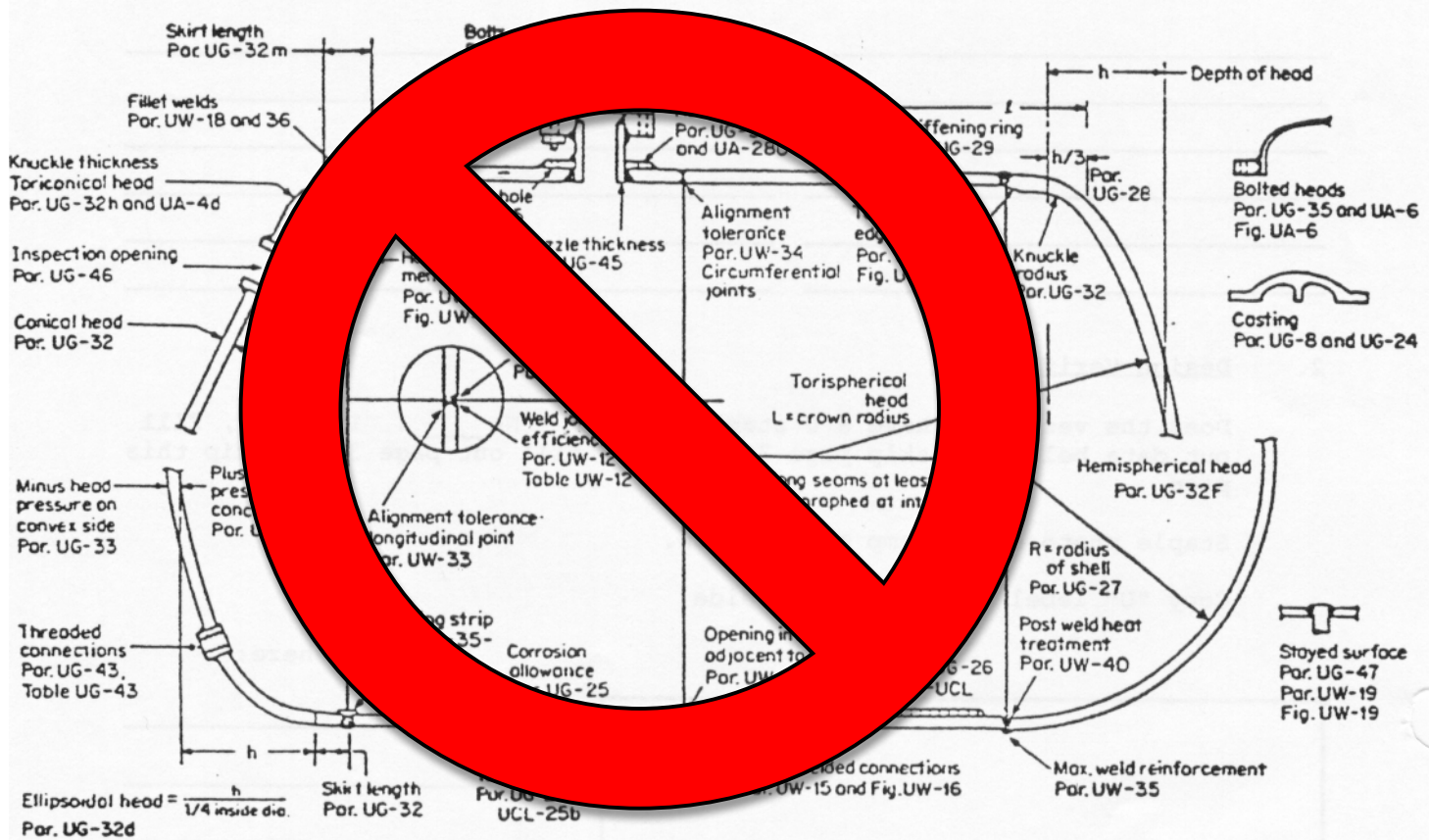
Rev. 06/2009

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v10.11.12 2/405

v10.18.12 2 / 424

Provide ASME design calculations in an appendix. On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. (Only for non-coded vessels)



2B.

THE LAPD MOLECULAR SIEVE FILTER VESSEL IS A CODE STAMPED ASME VESSEL. THIS SECTION IS NOT REQUIRED.

Item	Reference ASME Code Section	CALCULATION RESULT	
		(Required thickness or stress level vs. actual thickness calculated stress level)	
		VS	
		VS	
		VS	
		VS	
		VS	

3. System Venting Verification Provide the vent system schematic.

Does the venting system follow the Code UG-125 through UG-137?

Yes X No

Does the venting system also follow the Compressed Gas Association Standards S-1.1 and S-1.3?

Yes X No

A "no" response to both of the two proceeding questions requires a justification and statement regarding what standards were applied to verify system venting is adequate.

List of reliefs and settings:

Manufacturer	Model #	Set Pressure	Flow Rate	Size
Rockwood Swendeman	710NBEF-A	100 PSIG	282 SCFM AIR	1 x 1 ¼ inch

4. Operating Procedure

Is an operating procedure necessary for the safe operation of this vessel?

Yes No X (If "Yes", it must be appended)

5. Welding Information

Has the vessel been fabricated in a non-code shop? Yes No X

If "Yes", append a copy of the welding shop statement of welder qualification (Procedure Qualification Record, PQR) which references the Welding Procedure Specification (WPS) used to weld this vessel.

6. Existing and Unmanned Area Vessels

Is this vessel or any part thereof in the above categories?

Yes No X

If "Yes", follow the requirements for an Extended Engineering Note for Existing and Unmanned Area Vessels.

7. Exceptional Vessels

Is this vessel or any part thereof in the above category?

Yes No X

If "Yes", follow the requirements for an Extended Engineering Note for Exceptional Vessels.

THIS VESSEL CONFORMS TO FERMILAB ES&H MANUAL CHAPTER 5031			
Vessel Title	_____		
Vessel Number	_____		
Vessel Drawing No.	_____		
Maximum Allowable Working Pressure (MAWP)			
Internal Pressure	_____		
External Pressure	_____		
Working Temperature Range	_____	°F	_____ °F
Contents	_____		
Designer / Manufacturer	_____		
Test Pressure (if tested at Fermilab)	Acceptance Date _____		
_____ PSIG,	Hydraulic	_____	Pneumatic _____
Accepted as conforming to standard by			

Of Division / Section	_____		
NOTE: Any subsequent changes in content, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review and test.			

Figure 2. Sample of sticker to be completed and placed on vessel.

FORM R-1 REPORT OF REPAIR
in accordance with provisions of the *National Board Inspection Code*

1. Work performed by ABILITY ENGINEERING TECHNOLOGY INC.
(name of repair organization)
16140 South Vincennes Avenue SOUTH HOLLAND, ILLINOIS 60473
(address)
(Form Registration No.)
J 8330
(PO No., Job No., etc.)
2. Owner FERMI NATIONAL ACCELERATOR LABORATORY
(name)
P.O. Box 500 BATAVIA, ILLINOIS 60510
(address)
3. Location of installation FERMI NATIONAL ACCELERATOR LABORATORY
(name)
P.O. Box 500 BATAVIA, ILLINOIS 60510
(address)
4. Item identification Pressure Vessel Name of original manufacturer EDEN CRYOGENICS
(boiler, pressure vessel or piping)
5. Identifying nos.: 02128-03 10 - - 2010
(mfg. serial no.) (National Board No.) (Jurisdiction No.) (other) (year built)
6. NBIC Edition/Addenda: 2011
(edition) (addenda)
- Original Code of Construction for Item: ASME B. & P.V. CODE SECTION VIII DIVISION 1 2010
(name / section / division) (edition / addenda)
- Construction Code Used for Repair Performed: ASME B & P.V. CODE SECT. VIII DIV. 1 2010 add 2011
(name / section / division) (edition / addenda)
7. Repair Type: ☒ Welded ☐ Graphite Pressure Equipment ☐ FRP Pressure Equipment
8. Description of work: ☐ Form R-4, Report Supplementary Sheet is attached ☐ FFSA Form (NB-403) is attached
(use Form R-4, if necessary)
- TOP AND BOTTOM HEADS REPLACEMENT

- Pressure Test, if applied 252 psi MAWP 165 INT. / 15 EXT. psi
9. Replacement Parts. Attached are Manufacturer's Partial Data Reports or Form R-3s properly completed for the following items of this report:

(name of part, item number, data report type or Certificate of Compliance, mfg. name, and identifying stamp)

10. Remarks:

CERTIFICATE OF COMPLIANCE

I, MAREK HABER, certify that to the best of my knowledge and belief the statements in this report are correct and that all material, construction, and workmanship on this Repair conforms to the *National Board Inspection Code*.
National Board "R" Certificate of Authorization No. R-8339 expires on 04/19/2014
Date 7/02/12, ABILITY ENGINEERING TECHNOLOGY INC. Signed Marek Haber
(name of repair organization) (authorized representative)


CERTIFICATE OF INSPECTION

I, WILLIAM MOERZ, holding a valid Commission issued by The National Board of Boiler and Pressure Vessel Inspectors and certificate of competency, where required, issued by the Jurisdiction of IL and employed by HSB of CT have inspected the work described in this report on JUL 3, 2012 and state that to the best of my knowledge and belief this work complies with the applicable requirements of the *National Board Inspection Code*.
By signing this certificate, neither the undersigned nor my employer makes any warranty, expressed or implied, concerning the work described in this report. Furthermore, neither the undersigned nor my employer shall be liable in any manner for any personal injury, property damage or loss of any kind arising from or connected with this inspection.
Date JUL 3, 2012 Signed [Signature] Commissions 14061A 1L2235
(inspector) (National Board and Jurisdiction No.)

TECHNICAL APPENDIX FORM (TA5031) FOR PRESSURE VESSELS
PRESSURE VESSEL ENGINEERING NOTE PER CHAPTER 5031

Prepared by: Terry Tope
Preparation date: 6.12.12

1. Description and Identification
Fill in the label information below:

THIS VESSEL CONFORMS TO FERMILAB ES&H MANUAL CHAPTER 5031	
Vessel Title	<u>LAPD Oxygen Filter Vessel 2</u>
Vessel Number	<u>PPD10150 (PPD-10150)</u>
Vessel Drawing No.	<u>Eden Cryogenics LLC BC-02128-5800-01</u>
Maximum Allowable Working Pressure (MAWP)	
Internal Pressure	<u>165 psid</u>
External Pressure	<u>15 psid</u>
Working Temperature Range	<u>+932 °F</u> °F <u>-320 °F</u> °F
Contents	<u>Liquid argon and BASF CU-0226S</u>
Designer / Manufacturer	<u>Eden Cryogenics LLC</u>
Test Pressure (if tested at Fermilab)	Acceptance Date _____
_____ PSIG, Hydraulic _____	Pneumatic _____
Accepted as conforming to standard by	
<u></u>	
Of Division / Section	<u>PPD</u> Date: <u>10/17/2012</u>

← Obtain from Division/Section Safety Officer

← Document per Chapter 5034 of the Fermilab ES&H Manual

← Actual signature required

NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review.

Reviewed by: ROGER RABEHL
(Print Name)

Signature:  Date: 10/15/12

Director's signature (or designee) if the vessel is for manned areas but doesn't conform to the requirements of the chapter.

Signature: _____ Date: _____

Fermilab ES&H Manual

TA 5031 - 1

Rev. 06/2009

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http://www-esh.fnal.gov/pls/default/esh_manuals.html

v10.11.12 7/405

Amendment No.:

Reviewed by:

Date:

Lab Property Number(s): n/a

Lab Location Code: 701030125 (obtain from safety officer)

Purpose of Vessel(s): Remove oxygen from liquid argon.

Vessel Capacity/Size: 22.5 gallon Diameter: 12.75 inches Length: 51.5 inches

Normal Operating Pressure (OP) 30 psid

MAWP-OP = 165 - 30 = 135 PSID

List the numbers of all pertinent drawings and the location of the originals.

Drawing #

Eden Cryogenics LLC BC-02128-5800-01

Location of Original

8445 Rausch Dr Plain City, OH 43064

Repair:

Fermilab 3942.330-MD-489456

Fermi National Accelerator Laboratory

Fermilab 3942.330-MD-489458

2. Design Verification

Is this vessel designed and built to meet the ASME BPVC or "Experiment Vessel" requirements?

Yes X No .

If "No" state the standard that was used .

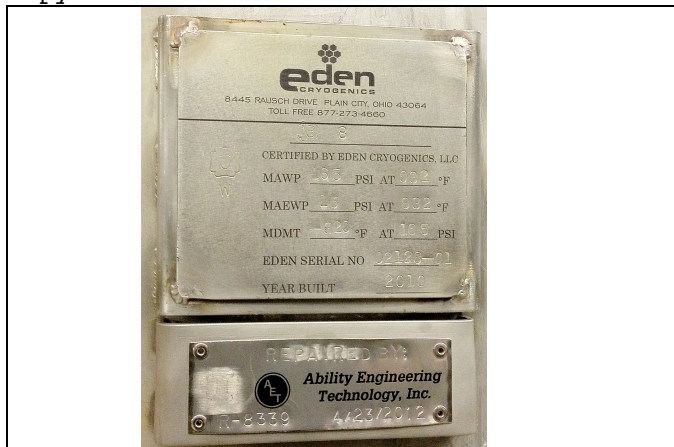
Demonstrate that design calculations of that standard have been made and that other requirements of that standard have been satisfied.

Skip to part 3 "system venting verification."

Does the vessel(s) have a U stamp? Yes X No . If "Yes", complete section 2A; if "No", complete section 2B.

A. Staple photo of U stamp plate below.

Copy "U" label details to the side



Copy data here:

NB 8

CERTIFIED BY EDEN CRYOGENICS LLC

MAWP 165 PSI AT 932 °F

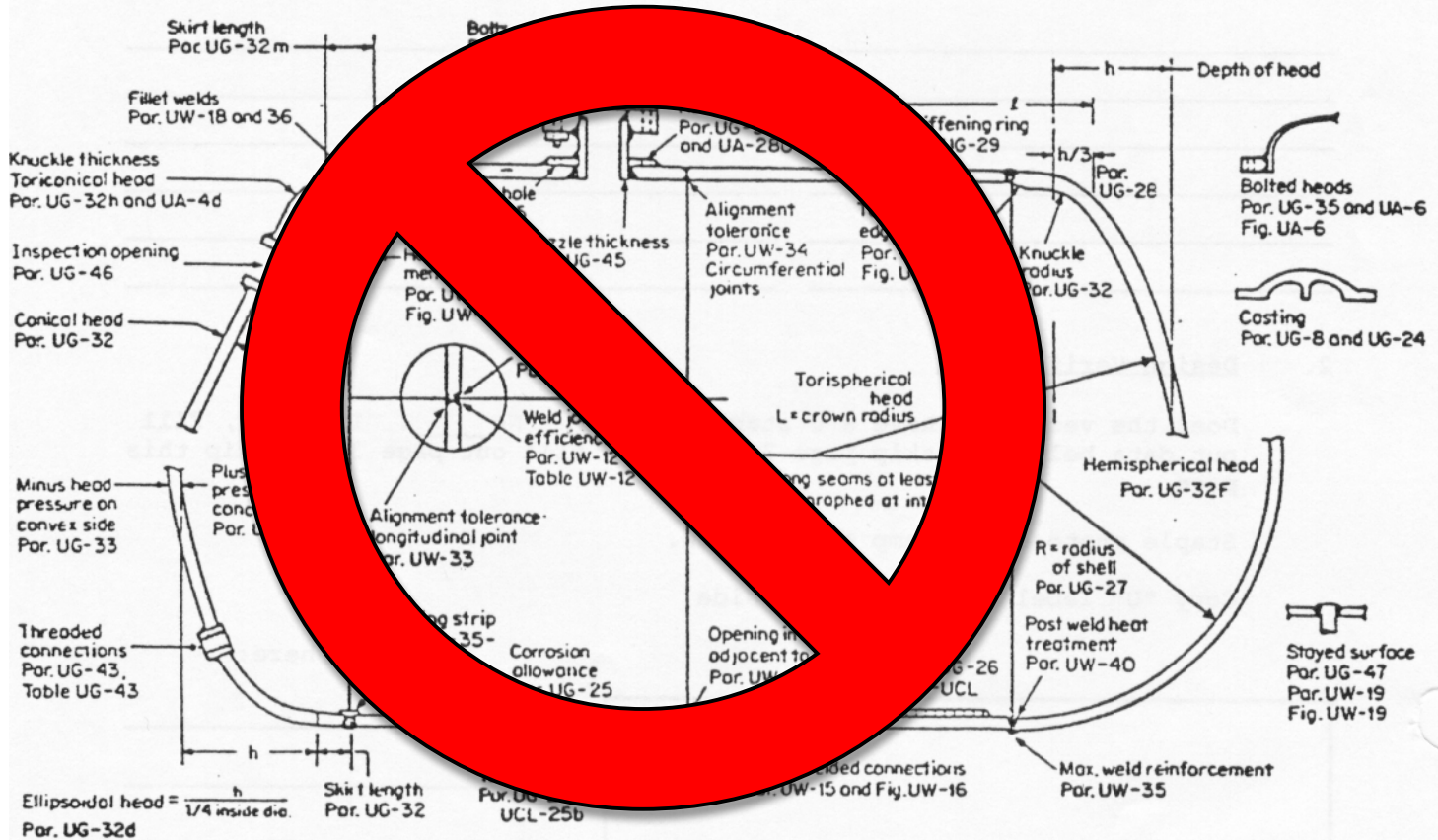
MAEWP 15 PSI AT 932 °F

MDMT -320 °F at 165 PSI

EDEN SERIAL NO 02128-01

YEAR BUILT 2010

Provide ASME design calculations in an appendix. On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. (Only for non-coded vessels)



2B.

THE LAPD OXYGEN FILTER VESSEL IS A CODE STAMPED ASME VESSEL. THIS SECTION IS NOT REQUIRED.

Item	Reference ASME Code Section	CALCULATION RESULT (Required thickness or stress level vs. actual thickness calculated stress level)	
		VS	
		VS	
		VS	
		VS	
		VS	

3. System Venting Verification Provide the vent system schematic.

Does the venting system follow the Code UG-125 through UG-137?

Yes X No

Does the venting system also follow the Compressed Gas Association Standards S-1.1 and S-1.3?

Yes X No

A "no" response to both of the two proceeding questions requires a justification and statement regarding what standards were applied to verify system venting is adequate.

List of reliefs and settings:

Manufacturer	Model #	Set Pressure	Flow Rate	Size
Rockwood Swendeman	710NBEF-A	100 PSIG	282 SCFM AIR	1 x 1 ¼ inch

4. Operating Procedure

Is an operating procedure necessary for the safe operation of this vessel?

Yes No X (If "Yes", it must be appended)

5. Welding Information

Has the vessel been fabricated in a non-code shop? Yes No X

If "Yes", append a copy of the welding shop statement of welder qualification (Procedure Qualification Record, PQR) which references the Welding Procedure Specification (WPS) used to weld this vessel.

6. Existing and Unmanned Area Vessels

Is this vessel or any part thereof in the above categories?

Yes No X

If "Yes", follow the requirements for an Extended Engineering Note for Existing and Unmanned Area Vessels.

7. Exceptional Vessels

Is this vessel or any part thereof in the above category?

Yes No X

If "Yes", follow the requirements for an Extended Engineering Note for Exceptional Vessels.

THIS VESSEL CONFORMS TO FERMILAB ES&H MANUAL CHAPTER 5031			
Vessel Title	_____		
Vessel Number	_____		
Vessel Drawing No.	_____		
Maximum Allowable Working Pressure (MAWP)			
Internal Pressure	_____		
External Pressure	_____		
Working Temperature Range	_____ °F	_____ °F	
Contents	_____		
Designer / Manufacturer	_____		
Test Pressure (if tested at Fermilab)	Acceptance Date	_____	
_____ PSIG,	Hydraulic	_____ Pneumatic	_____
Accepted as conforming to standard by			

Of Division / Section	_____		
NOTE: Any subsequent changes in content, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review and test.			

Figure 2. Sample of sticker to be completed and placed on vessel.

FORM R-1 REPORT OF REPAIR

in accordance with provisions of the *National Board Inspection Code*

1. Work performed by ABILITY ENGINEERING TECHNOLOGY INC.
(name of repair organization)
16140 South Vincennes Avenue SOUTH HOLLAND, ILLINOIS 60473
(address)
(Form Registration No.) J 8302
(PO No., Job No., etc.)
2. Owner FERMI NATIONAL ACCELERATOR LABORATORY
(name)
P.O. Box 500 BATAVIA, ILLINOIS 60510
(address)
3. Location of installation FERMI NATIONAL ACCELERATOR LABORATORY
(name)
P.O. Box 500 BATAVIA, ILLINOIS 60510
(address)
4. Item identification Pressure Vessel Name of original manufacturer EDEN CRYOGENICS
(boiler, pressure vessel or piping)
5. Identifying nos.: 02128-01 8 - - 2010
(mfg. serial no.) (National Board No.) (Jurisdiction No.) (other) (year built)
6. NBIC Edition/Addenda: 2011 2010
(edition) (addenda)
Original Code of Construction for Item: ASME B. & P.V. CODE SECTION VIII DIVISION 1 2010
(name / section / division) (edition / addenda)
Construction Code Used for Repair Performed: ASME B & P.V. CODE SECT. VIII DIV. 1 2010 add 2011
(name / section / division) (edition / addenda)
7. Repair Type: ☒ Welded ☐ Graphite Pressure Equipment ☐ FRP Pressure Equipment
8. Description of work: ☐ Form R-4, Report Supplementary Sheet is attached ☐ FFSA Form (NB-403) is attached
(use Form R-4, if necessary)

TOP AND BOTTOM HEADS REPLACEMENT

9. Replacement Parts. Attached are Manufacturer's Partial Data Reports or Form R-3s properly completed for the following items of this report:
Pressure Test, if applied 252 psi MAWP 165 INT. / 15 EXT. psi

(name of part, item number, data report type or Certificate of Compliance, mfg. name, and identifying stamp)

10. Remarks:

CERTIFICATE OF COMPLIANCE

I, MAREK HABER, certify that to the best of my knowledge and belief the statements in this report are correct and that all material, construction, and workmanship on this Repair conforms to the *National Board Inspection Code*.
National Board "R" Certificate of Authorization No. R-8339 expires on 04/19/2014
Date 04/12/2012, ABILITY ENGINEERING TECHNOLOGY INC. Signed Marek Haber
(name of repair organization) (authorized representative)

CERTIFICATE OF INSPECTION

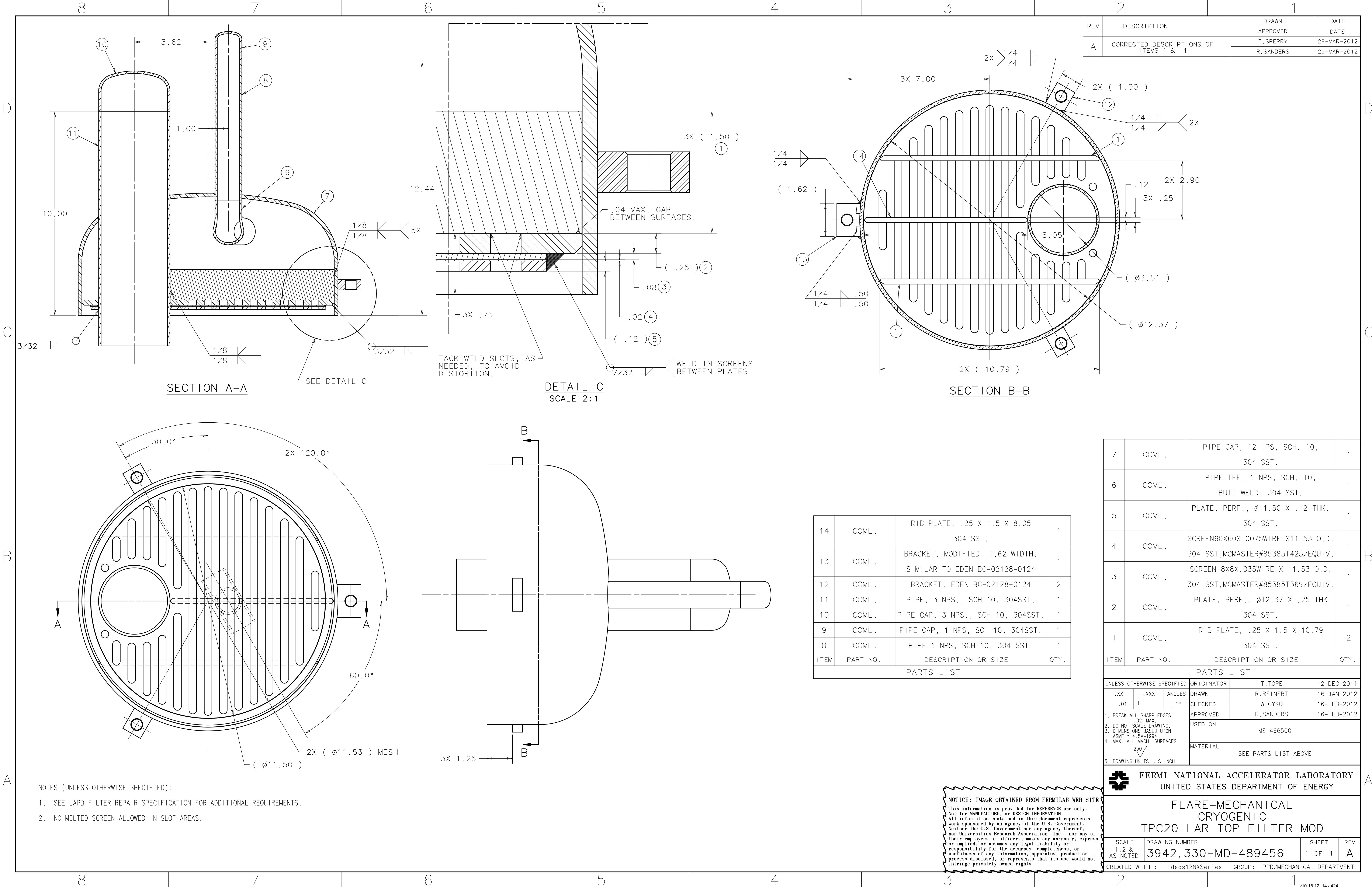
I, WILLIAM MOERS, holding a valid Commission issued by The National Board of Boiler and Pressure Vessel Inspectors and certificate of competency, where required, issued by the Jurisdiction of IL and employed by HSB of CT have inspected the work described in this report on 4-24-12 and state that to the best of my knowledge and belief this work complies with the applicable requirements of the *National Board Inspection Code*.
By signing this certificate, neither the undersigned nor my employer makes any warranty, expressed or implied, concerning the work described in this report. Furthermore, neither the undersigned nor my employer shall be liable in any manner for any personal injury, property damage or loss of any kind arising from or connected with this inspection.
Date 4-24-12 Signed William Moers Commissions 14061A IL 2235
(inspector) (National Board and Jurisdiction No.)

LAPD Filter Repair Notes

During the 1st LAPD run some filter material made it out of the filter vessels and into the piping. The filter material was contained within the filter vessels by sintered metal discs. The spare filter vessel that was never installed was examined by borescope (LAPD purchased 3 identical filter vessels – only two of which were put into service during the 1st run). The top sintered metal disc was found to have a small weld crack thru which filter material could leak out. This is not a pressure containment issue. It was assumed the installed filters had this same weld crack failure from the beginning and this was later confirmed. Both filter vessels were cut out of the piping. The repair consisted of cutting off both the top and bottom pressure vessel heads that contain the sintered metal discs. New heads were fabricated and welded on the vessel that contain screen between slotted plates instead of sintered metal discs. The screens provide particulate filtration while the slotted plates support the weight of the filter material and react the forces due to the pressure drop across the bed. The screen design is shown in FNAL drawings #489456 and #489458.

First the spare filter vessel was sent out for repair. This filter vessel was installed in place of the oxygen filter used during the 1st LAPD run. A new pressure vessel engineering note (with a unique vessel number) was created for this vessel which is identical to the original oxygen filter pressure vessel engineering note except that the repair is noted.

The filter which held the molecular sieve was sent out as the 2nd repair. Since this filter vessel will still be used to hold molecular sieve after the repair, the existing pressure vessel engineering note is amended (No. 1) to note the repair.



NOTES (UNLESS OTHERWISE SPECIFIED):

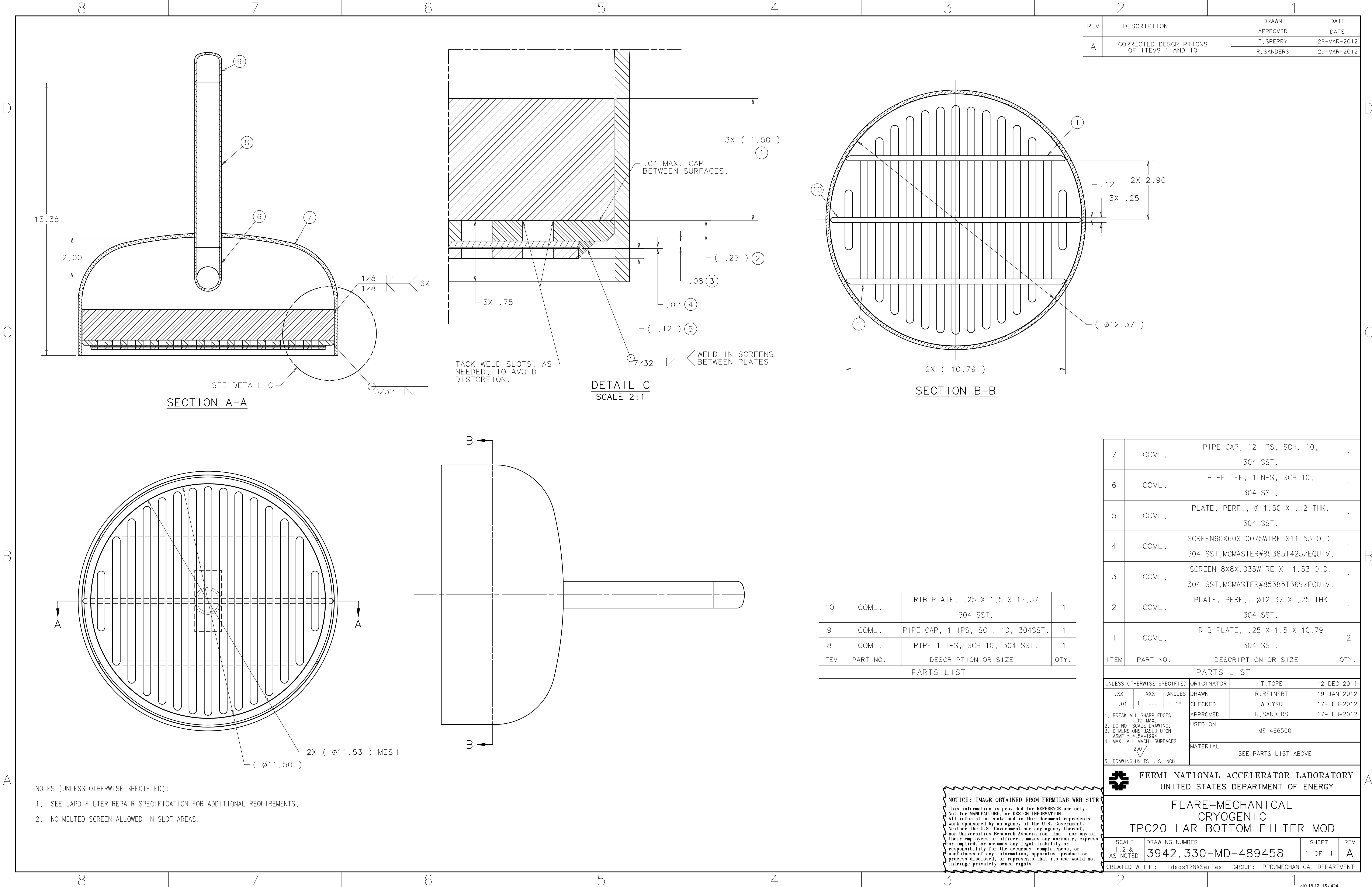
1. SEE LAPD FILTER REPAIR SPECIFICATION FOR ADDITIONAL REQUIREMENTS.
2. NO MELTED SCREEN ALLOWED IN SLOT AREAS.

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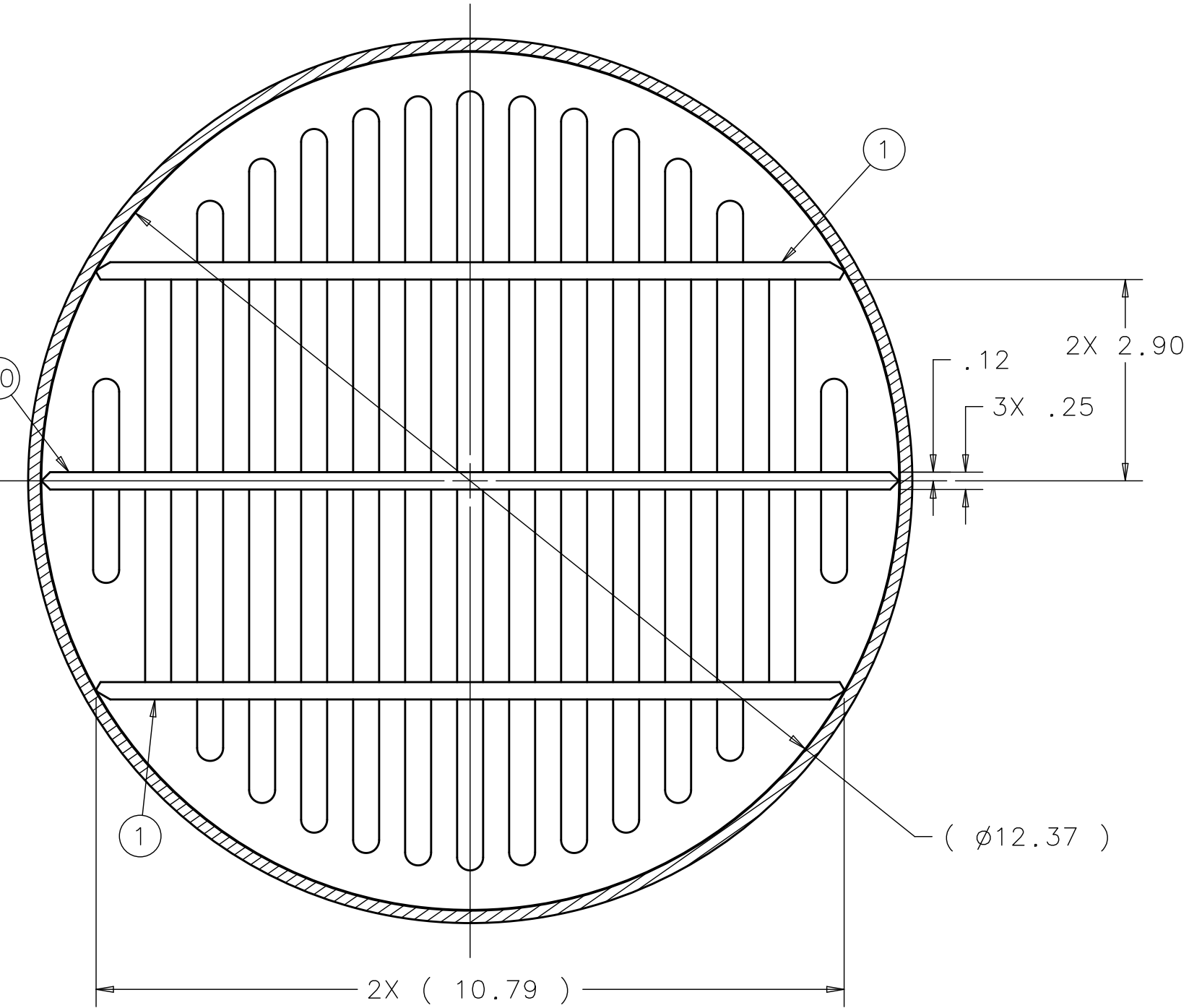
7	COML.	PIPE CAP, 12 IPS, SCH. 10, 304 SST.	1
6	COML.	PIPE TEE, 1 NPS, SCH. 10, BUTT WELD, 304 SST.	1
5	COML.	PLATE, PERF., ϕ 11.50 X .12 THK. 304 SST.	1
4	COML.	SCREEN60X60X.0075WIRE X11.53 O.D. 304 SST,MCMASER#85385T425/EQUIV.	1
3	COML.	SCREEN 8X8X.035WIRE X 11.53 O.D. 304 SST,MCMASER#85385T369/EQUIV.	1
2	COML.	PLATE, PERF., ϕ 12.37 X .25 THK 304 SST.	1
1	COML.	RIB PLATE, .25 X 1.5 X 10.79 304 SST.	2
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST			
UNLESS OTHERWISE SPECIFIED 1. BREAK ALL SHARP EDGES 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ASME Y14.5M-1994 4. MAX. ALL MACH. SURFACES 5. DRAWING UNITS: U.S. INCH	ORIGINATOR	T.TOPE	12-DEC-2011
	DRAWN	R.REINERT	16-JAN-2012
	CHECKED	W.CYKO	16-FEB-2012
	APPROVED	R.SANDERS	16-FEB-2012
	USED ON	ME-466500	
MATERIAL		SEE PARTS LIST ABOVE	

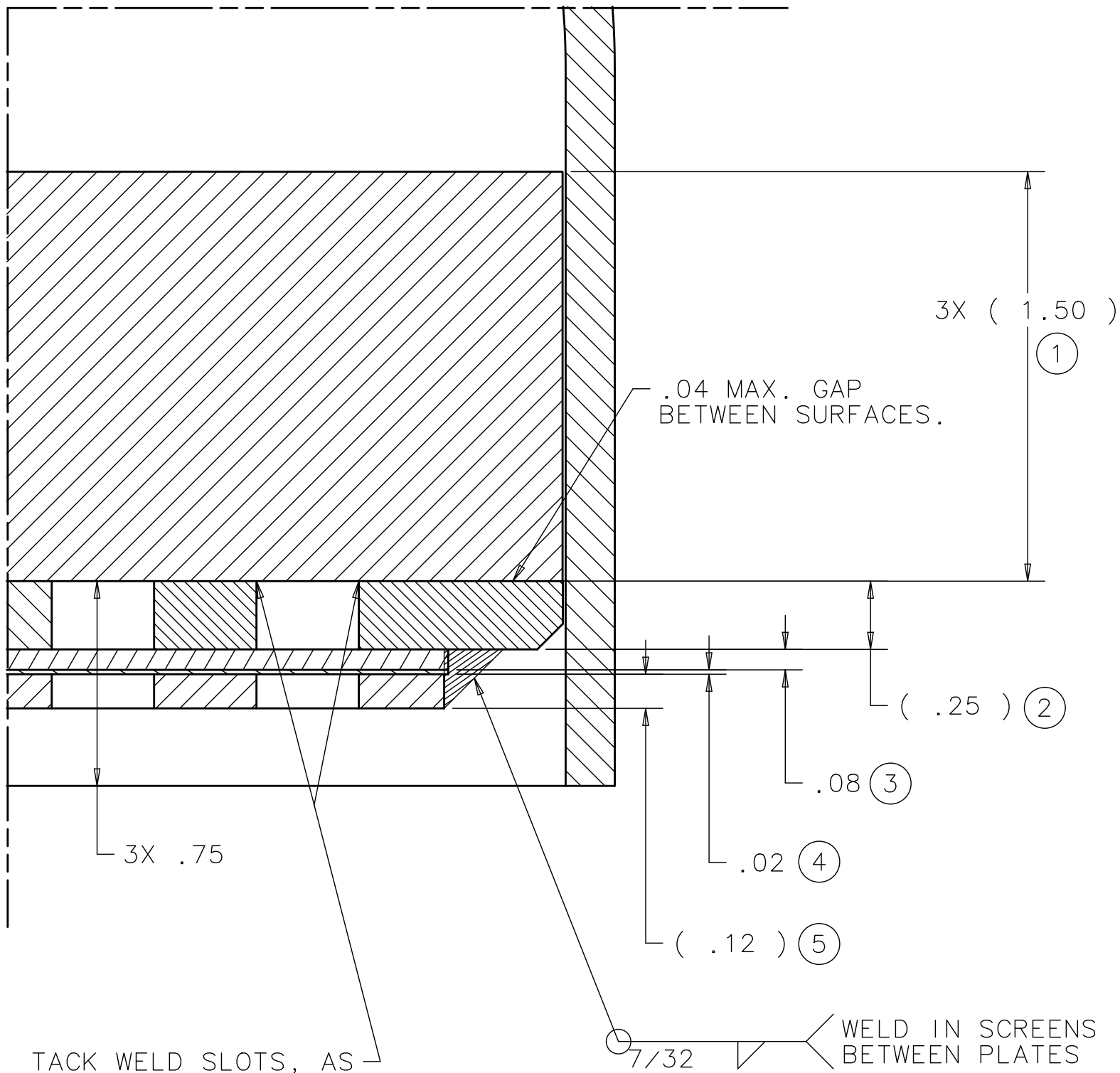
FERMI NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
FLARE-MECHANICAL CRYOGENIC TPC20 LAR TOP FILTER MOD			
SCALE 1:2 & AS NOTED	DRAWING NUMBER 3942.330-MD-489456	SHEET 1 OF 1	REV A
CREATED WITH : Ideas12NXSeries		GROUP: PPD/MECHANICAL DEPARTMENT	



REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE
A	CORRECTED DESCRIPTIONS OF ITEMS 1 AND 10	T.SPERRY	29-MAR-2012
		R.SANDERS	29-MAR-2012



SECTION B-B



DETAIL C
SCALE 2:1

10	COML.	RIB PLATE, .25 X 1.5 X 12.37 304 SST.	1
9	COML.	PIPE CAP, 1 IPS, SCH. 10, 304SST.	1
8	COML.	PIPE 1 IPS, SCH 10, 304 SST.	1
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			

7	COML.	PIPE CAP, 12 IPS, SCH. 10, 304 SST.	1
6	COML.	PIPE TEE, 1 NPS, SCH 10, 304 SST.	1
5	COML.	PLATE, PERF., ϕ 11.50 X .12 THK. 304 SST.	1
4	COML.	SCREEN60X60X.0075WIRE X11.53 O.D. 304 SST,MCMaster#85385T425/EQUIV.	1
3	COML.	SCREEN 8X8X.035WIRE X 11.53 O.D. 304 SST,MCMaster#85385T369/EQUIV.	1
2	COML.	PLATE, PERF., ϕ 12.37 X .25 THK 304 SST.	1
1	COML.	RIB PLATE, .25 X 1.5 X 10.79 304 SST.	2
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST			
UNLESS OTHERWISE SPECIFIED		ORIGINATOR	T.TOPE
.XX		DRAWN	R.REINERT
$\pm .01$		CHECKED	W.CYKO
1. BREAK ALL SHARP EDGES 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON 4. MAX. ALL MACH. SURFACES 5. DRAWING UNITS: U.S. INCH		APPROVED	R.SANDERS
		USED ON	ME-466500
		MATERIAL	SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
FLARE-MECHANICAL CRYOGENIC TPC20 LAR BOTTOM FILTER MOD			
SCALE 1:2 & AS NOTED	DRAWING NUMBER 3942.330-MD-489458	SHEET 1 OF 1	REV A
CREATED WITH : Ideas12NXSeries		GROUP: PPD/MECHANICAL DEPARTMENT	

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responsibility for the accuracy, completeness, or
usefulness of any information, apparatus, product or
process disclosed, or represents that its use would not
infringe privately owned rights.

- NOTES (UNLESS OTHERWISE SPECIFIED):
1. SEE LAPD FILTER REPAIR SPECIFICATION FOR ADDITIONAL REQUIREMENTS.
 2. NO MELTED SCREEN ALLOWED IN SLOT AREAS.

Relief Valve Sizing for the LAPD Filter Vessels and Other Information Relevant to the Pressure Vessel Engineering Notes

Two identical filter vessels are included in the LAPD liquid argon purification system. The vessels consist of an ASME code stamped inner vessel surrounded by an outer vessel that is the vacuum jacket. One vessel contains Sigma Aldrich 4A molecular sieve filter material while the other contains BASF CU-0226S oxygen filter material. CU-0226S is essentially a thin layer of copper covering a molecular sieve like substrate. The molecular sieve is regenerated using heated argon gas and the oxygen filter is regenerated using a mixture of heated 2.5% hydrogen in argon (2.5% hydrogen in argon is considered non-flammable). Both filters will be heated to 250 °C. The gas heaters are external to the filter vessels. The vessels will be used to purify argon gas during the gas recirculation phase which is powered by a bellows pump. Later the vessels will purify liquid argon circulated by a centrifugal pump.

The pressure relief devices for the LAPD liquid argon filter vessels were sized according to the Compressed Gas Association's CGA S-1.3—2008 document. This document is entitled, "Pressure Relief Device Standards Part 3—Stationary Storage Containers for Compressed Gases." It is available as part of Fermilab's Techstreet subscription.

These two identical vessels (PPD10139 and PPD10150) are each equipped with one code stamped pressure relief valve. The filter vessel containing molecular sieve filter material is protected by PSV-601-Ar while the oxygen filter material vessel is relieved by PSV-568-Ar. The basic vessel geometry is shown in Figure 1 and the manufacturer drawings are available in the appendix. The relief valves are each set at 100 psig (115 psid to vacuum). This is below each vessel's code stamped MAWP of 150 psig (165 psid to vacuum).

Fire Condition

First the fire condition is considered as it is more difficult to relieve than any other scenario. To begin the calculation, an estimate of the relief capacity required is computed. This number is then corrected for pressure drop and temperature rise in the line that leads to the reliefs if required. In CGA section 6.3.3 the following equation is used to calculate the minimum required flow capacity

$$Q_a = FG_iUA^{0.82}$$

where:

$U =$ Overall heat transfer coefficient to the liquid, $\frac{Btu}{hr \cdot ft^2 \cdot ^\circ F}$.

$F =$ Correction factor for pressure drop and temperature rise in line to relief valve, specified in 6.1.4., 1.0 in initial calculation.

$A =$ Average surface area of the inner and outer vessels (to be conservative the surface area of the outer vessel is used in all calculations).

$G_i =$ Gas factor for insulated containers.

$Q_a =$ Flow capacity required at applicable flow rating pressure and 60 °F in cubic feet per minute of free air.

The heat rate into the liquid is computed using SI units. All other calculations are performed in English units.

First the overall heat transfer coefficient to the liquid must be computed. For the fire condition it was assumed that the outer vessel is exposed to an environment that is at 922 K (1,660 °R) and the vacuum space between the inner and outer vessel has been filled with air at atmospheric pressure (air has a higher thermal conductivity than argon). For simplicity the vacuum jacket wall temperature is set to 922 K instead of computing a lower wall temperature based upon heat transfer from a 922 K ambient. The inner vessel wall will be at the saturation temperature of liquid argon at the flow rating pressure. The vacuum space contains six highly polished aluminum radiation shields. Aluminum radiation shields were

chosen because both filter vessels are regenerated at 523 K which would destroy Mylar based super insulation. The relief valves are set at 100 psig (6.89 bar gauge). For the fire condition it must be ensured that the pressure does not exceed 121% MAWP. However the 100 psig (6.89 bar gauge) relief valve set point is below the vessel 150 psig (10.34 bar gauge) MAWP. Thus the flow rating pressure used is $1.10 \times (100 + 14.7) - 14.7$, or 111.5 psig (7.68 bar gauge). The saturation temperature of liquid argon at 111.5 psig is 114.3 K (205.7 °R).

Two heat transfer mechanisms are considered for the fire condition. The first mechanism is radiation exchange between the vacuum jacket, the aluminum shields, and the inner vessel. In parallel to radiation, convection thru air filling the vacuum space transfers heat to the liquid argon. Figure 2 details the heat transfer paths.

Several simplifying assumptions were made. The surface area A_s for all calculations was taken as the surface area of a cylinder (including the top and bottom) whose outside diameter matches the inner diameter of the vacuum jacket. This is conservative because the surface area of the radiation shields and the inner vessel (A_{inner}) is significantly less than that of the vacuum jacket.

$$A_s = \frac{\pi}{4}(D)^2 \times 2 + \pi DL = \frac{\pi}{4}(23.5 \text{ in})^2 \times 2 + \pi \times 23.5 \text{ in} \times 75 \text{ in} = 6,404 \text{ in}^2 = 4.13 \text{ m}^2 = 44.48 \text{ ft}^2$$

The inner vessel has a surface area A_{inner} about 2.75x less than that of the vacuum jacket.

$$A_{inner} = \frac{\pi}{4}(D)^2 \times 2 + \pi DL = \frac{\pi}{4}(12.75 \text{ in})^2 \times 2 + \pi \times 12.75 \text{ in} \times 52 \text{ in} = 2,338 \text{ in}^2 = 1.51 \text{ m}^2 = 16.24 \text{ ft}^2$$

The emissivity of the inner surface of the vacuum jacket and the outer surface of the pressure vessel was taken as 1.0. Incropera and Dewitt's Fundamentals of Heat Transfer, Fourth Edition, lists the emissivity of highly oxidized stainless steel as 0.70 at 1,000 K such that 1.0 may be conservative. The emissivity of each of the highly polished aluminum radiation shields was estimated as 0.1. Incropera and Dewitt give an emissivity of 0.06 for highly polished aluminum at 600 K.

All heat transfer equations were solved simultaneously in EES, the program is available in the appendix. Using the vacuum jacket ID temperature and the inner vessel OD temperature as inputs, EES computed the temperature of each radiation shield and the corresponding heat flow. Example calculations are provided below.

Radiation is modeled as exchange between large infinite parallel planes in the following manner where subscript eight indicates the inner vessel and subscript seven the innermost radiation shield. Below is an example radiation calculation:

$$q_{rad_{78}} = \frac{A\sigma(T_7^4 - T_8^4)}{\frac{1}{\epsilon_7} + \frac{1}{\epsilon_8} - 1} = \frac{4.132 \text{ m}^2 \times \frac{5.67 \times 10^{-8} \text{ W}}{\text{m}^2 \times \text{K}^4} \times (324.6^4 - 114.3^4) \text{ K}^4}{\frac{1}{0.1} + \frac{1}{1} - 1} = 256.1 \text{ W}.$$

Thermal convection is modeled as cellular flow in a vertical cavity with different sidewall temperatures. Heat transfer thru the horizontal shields above the inner vessel will occur by conduction because the geometry is essentially a horizontal cavity heated from above. Thus using the convective heat transfer coefficients computed for the vertical cavity reasonably accounts for heat transfer in the horizontal portion above the inner vessel. Convective heat transfer thru the horizontal shields below the filter vessel is also accounted for using the heat transfer coefficients for the vertical cavity. A check of this assumption occurs in a later section.

For the gap between the inner vessel and the innermost radiation shield (T_8 and T_7), Incropera and Dewitt's equation 9.53 is used to compute the Nusselt number Nu_L .

$$Nu_L = 0.046 Ra_L^{1/3}, \quad Ra_L = \frac{g\beta(T_7 - T_8)L^3}{\alpha\nu}, \quad Nu_L = \frac{\bar{h}L}{k}, \quad q_{conv} = \bar{h}A_s(T_7 - T_8)$$

$$\left[\begin{array}{l} 1 < \frac{H}{L} < 40 \\ 1 < Pr < 20 \\ 10^6 < Ra_L < 10^9 \end{array} \right]$$

where

Ra_L = Rayleigh number, dimensionless.

\bar{h} = average heat transfer coefficient, W / (m² x K).

L = distance between the heated and cooled surfaces, 0.0794 m (3.125 in.) for the gap between the inner vessel and the innermost radiation shield. The gap between the radiation shields themselves and between the outermost radiation shield and the vacuum jacket is 0.009525 m (0.375 in.). These gaps were measured.

k = thermal conductivity of the air in the vacuum space, W / (m x K), evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces T_f (average of T_7 and T_8) by EES.

H = vertical height of the cavity, 1.651 meters (65 inches).

Pr = Prandtl number, dimensionless (ratio of the momentum and thermal diffusivities), evaluated at the average temperature of the two enclosure surfaces (average of T_7 and T_8).

g = gravitational acceleration, 9.8 m/s².

β = volumetric thermal expansion coefficient, 1/K, computed as $1 / T_f$.

α = thermal diffusivity, m²/s, evaluated for air at ambient pressure and T_f by EES.

ν = kinematic viscosity, m²/s, evaluated for air at ambient pressure and T_f by EES.

An example calculation is shown below:

$$Ra_{L78} = \frac{g\beta_{78}(T_7 - T_8)L_{78}^3}{\alpha_{78}v_{78}} = \frac{9.8 \text{ m}}{s^2} \times \frac{1}{219.4 \text{ K}} \times \frac{(324.6 - 114.3) \text{ K}}{1} \times \frac{0.07938^3 \text{ m}^3}{1} \times \frac{s}{0.00001209 \text{ m}^2} \times \frac{s}{0.000009036 \text{ m}^2} = 4.3 \times 10^7$$

$$Nu_{L78} = 0.046Ra_{L78}^{1/3} = 0.064 \times (4.3 \times 10^7)^{1/3} = 16.12, \quad \bar{h}_{78} = \frac{Nu_{L78}k_{78}}{L_{78}} = \frac{16.12}{1} \times \frac{0.0195 \text{ W}}{\text{m} \times \text{K}} \times \frac{1}{0.07938 \text{ m}} = 3.959 \frac{\text{W}}{\text{m}^2 \times \text{K}}$$

$$q_{conv78} = 3.959 \frac{\text{W}}{\text{m}^2 \times \text{K}} \times 4.132 \text{ m}^2 \times (324.6 - 114.3) \text{ K} = 3,441 \text{ W}$$

$$\left[\begin{array}{l} 1 < \frac{H}{L} < 40, \frac{H_{78}}{L_{78}} = \frac{1.651 \text{ m}}{0.07938 \text{ m}} = 20.8 \\ 1 < Pr < 20, Pr_{78} = 0.75 \\ 10^6 < Ra_L < 10^9, Ra_{L78} = 4.3 \times 10^7 \end{array} \right]$$

The correlation is applicable based on the H/L ratio and the Ra_L value, the Prandtl number is just out of the correlation's range.

The radiation and convection heat flows across each gap sum to a total heat flow that is equal across all gaps.

At the gap between the inner vessel and the first radiation shield the heat flow is computed as

$$q_{rad78} + q_{conv78} = q_{total} = 3,441 \text{ W} + 256.1 \text{ W} = 3,697 \text{ W}.$$

For the smaller gap between the radiation shields themselves and the outermost radiation shield and the vacuum jacket, equation 4.91 from the Handbook of Heat Transfer, 3rd Edition, is used to compute the Nusselt number Nu_L .

$$Nu_L = \left[1 + \left[\frac{0.0665 Ra_L^{1/3}}{1 + \left(\frac{9,000}{Ra_L} \right)^{1.4}} \right]^2 \right]^{1/2}, \quad \left[\begin{array}{l} 40 < \frac{H}{L} < 110 \\ Pr \approx 0.7 \\ Ra_L < 10^6 \end{array} \right]$$

An example calculation is shown below where subscript two indicates the outermost radiation shield and subscript one the vacuum jacket:

$$Ra_{L12} = \frac{g\beta_2(T_1 - T_2)L_{12}^3}{\alpha_{12}\nu_{12}} = \frac{9.8 \text{ m}}{s^2} \times \frac{1}{902.8 \text{ K}} \times \frac{(922 - 883.513) \text{ K}}{1} \times \frac{0.009525^3 \text{ m}^3}{1} \times \frac{s}{0.0001423 \text{ m}^2} \times \frac{s}{0.0001004 \text{ m}^2} = 25.26$$

$$Nu_{L12} = \left[1 + \left[\frac{0.0665 Ra_{L12}^{1/3}}{1 + \left(\frac{9,000}{Ra_{L12}} \right)^{1.4}} \right]^2 \right]^{1/2} = \left[1 + \left[\frac{0.0665(25.26)^{1/3}}{1 + \left(\frac{9,000}{25.26} \right)^{1.4}} \right]^2 \right]^{1/2} = 1, \quad \bar{h}_{12} = \frac{Nu_{L12}k_{12}}{L_{12}} = \frac{1}{1} \times \frac{0.06241 \text{ W}}{\text{m} \times \text{K}} \times \frac{1}{0.00925 \text{ m}} = 6.552 \frac{\text{W}}{\text{m}^2 \times \text{K}}$$

$$q_{conv12} = 6.552 \frac{\text{W}}{\text{m}^2 \times \text{K}} \times 4.132 \text{ m}^2 \times (922 - 883.513) \text{ K} = 1,042 \text{ W}$$

$$\left[\begin{array}{l} 40 < \frac{H}{L} < 110, \frac{H_{12}}{L_{12}} = \frac{1.651 \text{ m}}{0.009525 \text{ m}} = 173 \\ 1 < Pr < 20, Pr_{12} = 0.71 \\ Ra_L < 10^6, Ra_{L12} = 25.26 \end{array} \right]$$

The Nusselt number is 1 which indicates conduction is the primary heat transfer mechanism across the smaller gaps between the radiation shields and between the outermost radiation shield and the vacuum jacket. The Rayleigh number of 25.26, which much less than the critical value of 1,708 at which buoyancy forces begin to overcome viscous forces, suggests that in the horizontal gaps between the radiation shields below the inner vessel heat transfer occurs by conduction and thus the heat transfer coefficients calculated for the vertical radiation shield gaps are reasonable to use for the lower horizontal shields.

The corresponding radiation contribution across the gap between the vacuum jacket and the outermost radiation shield is:

$$q_{rad12} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} = \frac{4.132 \text{ m}^2 \times \frac{5.67 \times 10^{-8} \text{ W}}{\text{m}^2 \times \text{K}^4} \times (922^4 - 883.513^4) \text{ K}^4}{\frac{1}{1} + \frac{1}{0.1} - 1} = 2,654.8 \text{ W}.$$

The total heat flow again sums to:

$$q_{rad12} + q_{conv12} = q_{total} = 2,655 \text{ W} + 1,042 \text{ W} = 3,697 \text{ W}.$$

For the CGA calculation this heat flow must be converted to an overall heat transfer coefficient to the liquid.

$$h = \frac{q}{A\Delta T} = \frac{3,697 \text{ W}}{4.132 \text{ m}^2(922 - 114.3) \text{ K}} \times \frac{1}{1 \text{ W}} \frac{1 \text{ J}}{\text{sec}} \times \frac{1 \text{ Btu}}{1055.06 \text{ J}} \times \frac{3600 \text{ sec}}{\text{hr}} \times \frac{1 \text{ m}^2}{10.7639 \text{ ft}^2} \times \frac{1 \text{ K}}{1.8 \text{ R}} = 0.195 \frac{\text{Btu}}{\text{hr} \times \text{ft}^2 \times ^\circ\text{F}}$$

To calculate the initial estimate of the relief capacity needed, a gas factor, G_i , must be computed. From page 25 of the CGA S-1.3—2008, when the flow rating pressure is less than 40% of the critical pressure ($\frac{126.2 \text{ psia}}{705.4 \text{ psia}} \cdot 100 = 17.9\%$), the following is used to compute G_i .

$$G_i = \frac{73.4(1660 - T)}{CL} \sqrt{\frac{ZT}{M}}$$

where

$L =$ Latent heat of product at flow rating pressure, $60.68 \frac{\text{Btu}}{\text{lb}_m}$ for saturated conditions at 126.2 psia .

$C =$ Constant for vapor related to ratio of specific heats ($k=c_p/c_v$) at standard conditions. $k = 1.67$ for Argon at 60°F and 14.696 psia (from EES) which corresponds to $C = 378$ (Table 4 of CGA S-1.3—2008).

$Z =$ Compressibility factor for saturated vapor at 126.2 psia

$$Z = \frac{P_v}{RT}, \quad Z = \frac{126.2 \frac{\text{lb}_f}{\text{in}^2} \times 0.3685 \frac{\text{ft}^3}{\text{lb}} 144 \frac{\text{in}^2}{\text{ft}^2}}{\frac{1545 \frac{\text{ft} \times \text{lb}_f}{\text{lbmol} \times ^\circ\text{R}}}{39.948 \frac{\text{lb}}{\text{lbmol}}} \times 205.7^\circ\text{R}} = 0.842.$$

$T =$ Flow rating temperature, 205.7°R .

$M =$ Molecular weight of gas, 39.948 for argon.

$v =$ specific volume, saturated vapor at flow rating pressure of 126.2 psia, $0.3685 \frac{\text{ft}^3}{\text{lb}_m}$.

G_i is calculated to be $\frac{73.4(1660 - 205.7)}{378 \times 60.68} \sqrt{\frac{0.842 \times 205.7}{39.948}} = 9.69$.

The uncorrected volumetric flow rate was found to be

$$Q_{ae} = 1.0 \times 9.69 \times 0.195 \times 44.48^{0.82} = 42.4 \frac{\text{ft}^3}{\text{min}} \text{ of free air.}$$

The relief valve is attached to the cryostat thru piping of length of about 6 feet, thus the correction factor F is calculated according to CGA section 6.1.4

$$F = \sqrt{\frac{P_i v_i}{P_v}}$$

where

P_i = Pressure at the inlet of the PRD in lb/in^2 .

v_i = Specific volume at the inlet of the PRD in ft^3/lb .

P = Flow rating pressure, 126.2 psia.

v = Specific volume of the fluid being relieved at the flow rating pressure and temperature defined in 6.1.3, 0.3685 ft^3/lb for saturated argon vapor at 126.2 psia.

The mass flow rate is calculated using CGA equation 6.1.4 a)

$$W = \frac{Q_{ae} C}{18.35} \sqrt{\frac{M}{ZT}}$$

where

Q_{ae} = Calculated flow capacity using the applicable formula from 6.2, 6.3.2, or **6.3.3** with $F = 1.0$, 42.4 ft^3/min of free air.

W = Required mass flow rate of lading through the PRD in lb_m/hr of the fluid being relieved.

C = Constant for vapor related to ratio of specific heats ($k = c_p/c_v$) at standard conditions. $k = 1.67$ for Argon at 60 °F and 14.696 psia which corresponds to $C = 378$.

M = Molecular weight of the fluid, 39.948 for argon.

T = Temperature specified in 6.1.3, 205.7 °R for saturated argon vapor at 126.2 psia.

Z = Compressibility factor at the temperature specified in 6.1.3 and flow rating pressure, 0.842.

$$W = \frac{Q_{ae} C}{18.35} \sqrt{\frac{M}{ZT}} = \frac{42.4 \times 378}{18.35} \sqrt{\frac{39.948}{0.842 \times 205.7}} = 419.5 \frac{\text{lb}_m}{\text{hr}}.$$

The temperature at the inlet of the PRD is computed from 6.1.4 b) where

$$T_i = 2145 - \frac{2145 - T_s}{e^{\frac{5.24 DL}{WC_p}}}$$

T_i = Temperature at the inlet to the PRD during full flow conditions in degrees Rankine.

T_s = Temperature specified in 6.1.3, 205.7 °R.

$D =$ Outside diameter in inches of the line between the container and the PRD, 1.315 inches for the 1 inch SCH 10 pipe.

$L =$ Length of piping between the container and PRD, 6 ft.

$e =$ 2.71828, the base of natural logarithms.

$W =$ Required mass flow rate of lading through the PRD, 419.5 lbm/hr.

$C_p =$ Average specific heat at constant pressure of lading between T_s and 1660 °R, 0.1281 Btu/ (lbm x °R). This was found by fitting a curve to C_p data provided by the NIST Standard Reference Database 23, Version 8.0 and then numerically integrating the curve to find the average C_p value. The details are available in the appendix.

$$T_i = 2145 - \frac{2145 - T_s}{e^{\frac{5.24DL}{WC_p}}} = 2145 - \frac{2145 - 205.7}{e^{\frac{5.24 \times 1.315 \times 6}{419.5 \times 0.1281}}} = 1,246 \text{ } ^\circ R.$$

The pressure at the inlet of the relief valve is calculated using 6.1.4 c)

$$P_i = P - 3.36 \times 10^{-6} \frac{f l W^2 v}{d^5}$$

$P_i =$ Pressure at the inlet of the PRD in lb/in².

$P =$ Flow rating pressure, 126.2 psia.

$f =$ Friction factor, calculated using the methods outline in Crane 410 11/2009 edition – see below calculations.

$\ell =$ Equivalent length of pipe in ft, calculated using the methods of Crane 410 – see below calculations.

$W =$ Required mass flow through the PRD, 419.5 lbm/hr.

$v =$ Specific volume of the fluid being relieved at the flow rating pressure and average temperature between T_i (1,246 °R) and T_s (205.7 °R), 1.546 ft³/lb at 126.2 psia and 726.1 °R.

$d =$ Internal diameter of the pipe, 1.097 inches for 1 inch SCH 10 pipe.

The path to the relief valve has 6 feet of straight pipe. In addition to the straight pipe it flows thru four elbows and the branches of two tees. Each elbow is a 1 inch SCH 10 short radius elbow which has a r/d of 1. Thus the K value for one bend is $20 \times f_T$ from page A-30 of Crane 410. f_T is the friction factor in the zone of complete turbulence which is equal to 0.02224 for clean commercial steel pipe with an inside diameter of 1.097 inches according to the plot on page A-26 of Crane 410.

Diverging flow thru the branch of a 90 degree tee where the branch flow is the entire flow results in a K value of 0.64 according to Figure 2-16 on Crane 410 page 2-16. A K value of 0.78 is included to account for entrance losses.

The resistance coefficient for straight piping is computed from Crane equation 2-4 which is

$$K = f \frac{L}{D}.$$

f is computed using the Colebrook equation which is Crane 410 equation 1-20

$$\frac{1}{\sqrt{f}} = -2.0 \log \left(\frac{\varepsilon}{3.7D} + \frac{2.51}{R_e \sqrt{f}} \right).$$

The Reynolds number R_e is computed using Crane 410 equation 6-3 where the dynamic viscosity μ was calculated by EES to be 0.028978 centipoise at 126.2 psia and the average temperature between T_i and T_s of 726.1 °R.

$$R_e = 6.315 \frac{W}{d\mu} = 6.315 \frac{419.5}{1.097 \times 0.028978} = 83,336.$$

ε , the absolute roughness, was estimated as 0.00015 using the data on Crane 410 page A-24 for commercial steel.

Using EES to solve the implicit equation Colebrook, f was computed as 0.02447 (see appendix for EES program).

Thus the total resistance between the vessel and the relief valve is computed as

$$K = 4 \times 20 f_T + 2 \times 0.64 + 0.78 + f \frac{L}{D} = 4 \times 20 \times 0.02224 + 2 \times 0.64 + 0.78 + 0.02447 \frac{6 \text{ ft}}{1.097 \frac{\text{in}}{12 \frac{\text{in}}{\text{ft}}}} = 5.445.$$

The equivalent length of straight pipe is then calculated as follows:

$$L = \frac{KD}{f} = \frac{5.445 \times \frac{1.097 \text{ in}}{12 \frac{\text{in}}{\text{ft}}}}{0.02447} = 20.34 \text{ ft}$$

The inlet pressure drop is then calculated as

$$P_i = 126.2 - 3.36 \times 10^{-6} \frac{f l W^2 v}{d^5} = \frac{0.02447 \times 20.34 \times 415.9^2 \times 1.546}{1.097^5} = 126.2 - 0.282 = 125.918 \text{ psia}.$$

The specific volume of the vapor at the relief valve inlet conditions of 125.918 psia and 1,246 °R, v_i , is 2.666 ft³/lbm.

The correction factor F is then calculated per 6.1.4 e).

$$F = \sqrt{\frac{P_i v_i}{P_v}} = \sqrt{\frac{125.918 \times 2.666}{126.2 \times 0.3685}} = 2.687$$

$$Q_{ae} = 2.687 \times 9.69 \times 0.195 \times 44.48^{0.82} = 114.1 \frac{\text{ft}^3}{\text{min}} \text{ of free air.}$$

The Rockwood Swendeman model 710NBEF-A relief valve protecting the cryostat has a discharge capacity of 282 cubic feet per minute of air at 10% overpressure beyond its 100 psig set point and thus should easily handle the fire case. Relief valve data available in the appendix.

As an additional check, pressure drop thru the filter bed and the screen used to retain the filter material is estimated to ensure that it is negligible. The fire case, which generates the largest mass flow rate, assumes a filter vessel full of liquid argon such that the saturated vapor generated due to this peak mass flow case does not have to travel the entire length of the filter bed to reach the relief valve. To be conservative pressure drop thru the filter beds is calculated assuming the argon gas has warmed from the flow rating temperature of 114.3 K to 300 K and its assumed that the all the vapor generated passes thru the entire filter bed.

The filter pressure drop equation is taken from Union Carbide Molecular Sieve literature which is available in the appendix.

$$\Delta P_{filter} = \frac{f_T C_t G^2 L}{\rho_{filter} D_p},$$

where

f_T = friction factor determined from the modified Reynolds's number of $Re_{mod} = \frac{D_p G}{\mu_{filter}}$ and plot in the Union Carbide Molecular Sieve literature

C_t = pressure drop coefficient determined from plot in Union Carbide literature for external void fraction of 0.37, 3.6×10^{-10}

W = argon mass flow rate, 419.5 lb/hr for the fire case

$$G = \text{superficial mass velocity, } G = \frac{W}{A_{filter}} = \frac{419.5 \frac{\text{lb}}{\text{hr}}}{0.8373 \text{ ft}^2} = 501.02 \frac{\text{lb}}{\text{hr} \cdot \text{ft}^2}$$

A_{filter} = cross-sectional area of the filter, 0.8373 ft² (12.39 in. ID for 12 inch SCH 10 pipe)

μ_{filter} = argon gas viscosity, 0.05534 lb/(ft*hr) (argon gas at 80.3 °F and 126.2 psia)

D_p = effective particle diameter of filter material, $D_p = 0.00336$ ft. for oxygen filter material, $D_p = 0.00666$ ft. for molecular sieve material.

L = length of filter bed, 3.33 ft.

ρ_{filter} = argon gas density, 0.874 lb / ft³ (argon gas at 80.3 °F and 126.2 psia)

The modified Reynolds number for each filter is

$$\text{Re}_{\text{mod,oxygen}} = \frac{(.00336 \text{ ft})}{0.05534 \frac{\text{lb}}{\text{ft} \cdot \text{hr}}} \frac{501.02 \text{ lb}}{\text{hr} \cdot \text{ft}^2} = 30.4, \quad \text{Re}_{\text{mod,molecular sieve}} = \frac{(.00666 \text{ ft})}{0.05534 \frac{\text{lb}}{\text{ft} \cdot \text{hr}}} \frac{501.02 \text{ lb}}{\text{hr} \cdot \text{ft}^2} = 60.3.$$

Based on the modified Reynolds numbers, f_T is 2.55 the oxygen filter and 1.78 for the molecular sieve.

$$\Delta P_{\text{oxygen}} = \frac{2.55 \times 3.6 \times 10^{-10} \times 501.02^2 \times 3.33}{0.874 \times 0.00336} = 0.261 \text{ psi}$$

$$\Delta P_{\text{molecular}} = \frac{1.78 \times 3.6 \times 10^{-10} \times 501.02^2 \times 3.33}{0.874 \times 0.00666} = 0.092 \text{ psi}$$

Thus the pressure drop thru the filter beds themselves is negligible and in reality would likely be much lower due to colder vapor temperatures and the fact that not all of the vapor would have to pass thru the entire bed.

Vapor generated during a relief event must pass thru the filter material retention screens. The screen is shown in FNAL drawing # 489456. The screen assembly consists of two slotted plates sandwiching two screens. Using ImageJ software the slot open area was calculated as 32 in² = 0.222 ft². Item 4 in drawing # 489456 will be referred to as screen 1 for calculation purposes and has a 60 x 60 mesh, 0.0075" wire diameter, 0.009" opening width, and 30.5% open area. Item 3 in drawing # 489456 will be referred to as screen 2 for calculation purposes and has a 8 x 8 mesh, 0.035" wire diameter, 0.09" opening width, and 51.8% open area.

The 5th edition of the Chemical Engineers' Handbook by Perry and Chilton has an equation for pressure drop thru screens on page 5-37. It states that flow thru a screen can be considered as flow thru a number of orifices or nozzles in parallel. It also notes that for a series of screens the over-all head loss is directly proportional to the number of screens in series and is not affected by either the spacing between successive screens or by their orientation with respect to one another.

Since the two screens are different sizes, the pressure drop will be calculated individually across each screen using equation 5-100 from the Chemical Engineers' Handbook.

$$\Delta h = \left(\frac{n}{C^2} \right) \left(\frac{1 - \alpha^2}{\alpha^2} \right) \left(\frac{V^2}{2g_c} \right)$$

Δh = head lost, ft. of fluid flowing

n = number of screens in series, dimensionless, 1 because the screens are calculated individually

C = screen discharge coefficient, dimensionless, C is a function screen Reynolds number N_{Re}

α = fractional free projected area of the screen, dimensionless, 0.305 for screen 1 and 0.518 for screen 2

V = superficial velocity ahead of screen, ft/sec

g_c = dimensional constant, 32.17 (lb.)(ft.)/((lb. force)(sec²)

$$N_{Re} = \frac{D_s V \rho}{\alpha \mu}$$

D_s = aperture width, 0.00075 ft. for screen 1 and 0.0075 ft. for screen 2

ρ = fluid density, 0.874 lb/ft³ for argon gas at 126.2 psia and 80.3 °F

μ = fluid viscosity, 0.00001537 lb/ft-sec for argon gas at 126.2 psia and 80.3 °F

The superficial velocity ahead of the screen is calculated from the fire relief event mass flow rate and the open slot area

$$V = \frac{W}{\rho \times A_{screen}} = 419.5 \frac{lb}{hr} \times \frac{1 hr}{3600 sec} \times \frac{ft^3}{0.874 lb} \times \frac{1}{0.222 ft^2} = 0.6 \frac{ft}{sec}.$$

The screen Reynolds number for screen 1 is

$$N_{Re} = \frac{0.00075 \times 0.6 \times 0.874}{0.305 \times 0.00001537} = 83.9$$

and the screen Reynolds number for screen 2 is

$$N_{Re} = \frac{0.0075 \times 0.6 \times 0.874}{0.518 \times 0.00001537} = 494$$

such that the screen discharge coefficient C is 0.7852 for screen 1 and 1.155 for screen 2 according to figure 5-44 Chemical Engineers' Handbook.

The pressure drop for screen 1 is then

$$\Delta h = \left(\frac{1}{0.7852^2} \right) \left(\frac{1 - 0.305^2}{0.305^2} \right) \left(\frac{0.6^2}{2 \times 32.2} \right) = 0.088 ft = 0.088 ft \times \frac{0.874 lb}{ft^3} \times \frac{1 ft^2}{144 in^2} = 0.0005 psi$$

and for screen 2 is

$$\Delta h = \left(\frac{1}{1.155^2} \right) \left(\frac{1 - 0.518^2}{0.518^2} \right) \left(\frac{0.6^2}{2 \times 32.2} \right) = 0.011 ft = 0.011 ft \times \frac{0.874 lb}{ft^3} \times \frac{1 ft^2}{144 in^2} = 0.000067 psi.$$

Thus the filter material retention screens are not a significant restriction during a relieving event.

Loss of Vacuum Condition

Because the fire condition includes atmospheric air in the vacuum space, the preceding fire calculation also indicates the relief capacity is more than adequate for an operational loss of insulating vacuum.

Vapor Generation Due to Filter Regeneration Gas Heaters

Two Omega model AHPF-122 gas heaters (HTR-612-HAr & HTR-634-HAr), mounted externally with respect to the filter vessel assembly, can heat nitrogen or a non-flammable mixture of hydrogen/argon from room temperature to 250 C to regenerate the filters. The nitrogen is supplied by LN2 tanker # 22 which has a MAWP of 50 psig, thus the nitrogen

source cannot over pressurize the filter vessels. The premixed hydrogen/argon is supplied by a tube trailer. The tube trailer supply is relieved by PSV-108-H set at 100 psig such that the hydrogen/argon regeneration gas supply cannot over pressurize the filter vessels. PSV-108-H is identical to the relief valves protecting the filter pressure vessels such that its capacity of 282 SCFM at 100 psig air exceeds the 150 SCFM capacity of the Matheson Model 3201 pressure regulator connected to the tube trailer, PRV-106-HAr. See appendix for regulator details.

Temperature of the Inner Vessel

Although the filter regeneration gas flow cannot over pressurize the vessels, it must also be shown that the code stamped upper temperature limit of +932 °F cannot be exceeded. In addition to PLC PID heater control, two hardwired temperature interlocks protect the filter vessels. One interlock pair senses the heated gas temperature at the heater outputs (TE-635-HAr & TE-636-HAr), while the other interlock pair (TE-621-Ar & TE-626-Ar) looks at the temperatures at the inlet of the filter beds. These are hardwired temperature interlocks that are independent of the PLC and drop the heater AC power if the measured temperature exceeds +572 °F. To restart the heater AC power the temperature must drop below +572 °F and a physical reset button must be pushed.

Filling of the LAPD Tank

Liquid argon used to fill the LAPD tank will pass thru the filter vessels detailed in this pressure vessel note. The LAPD tank has a MAWP of 3 psig. To protect the LAPD tank during its fill, the supply tanker will have its liquid pump locked out. This pump lockout will be part of the filling procedure and verified by a Fermilab engineer. The MAWP of the liquid argon supply tanker will be verified at the time of the tankers arrival. It is believed the MAWP of the supply tanker will be 60 psig based upon vendor discussions such that the liquid argon supply tanker cannot over pressurize the filter vessels.

Liquid Argon Pump

A Barber-Nichols liquid argon pump receives liquid from the LAPD tank and pumps it through the filter vessels. According to the manufacturer, it can create a maximum differential pressure of 62.4 psi (pump curve available in the appendix). The maximum vapor pressure in the LAPD tank is 3 psig. The maximum liquid head height above the pump suction is 14 feet, assuming liquid reaches the highest point of the tank dished head which is 12 ft. and allowing for the 2 foot drop to the pump suction. Thus the maximum pressure available at the pump suction is

$$P_{\text{vapor}} + \rho_{\text{LAr}} \times g \times h = 3 \frac{\text{lbf}}{\text{in}^2} + 87 \frac{\text{lbf}}{\text{ft}^3} \times \frac{1 \text{ slug}}{32.2 \text{ lbf}} \times \frac{32.2 \text{ ft}}{\text{s}^2} \times 14 \text{ ft} \times \frac{1 \text{ ft}^2}{144 \text{ in}^2} \times \frac{\text{lbf} \times \text{s}^2}{\text{slug} \times \text{ft}} = 11.5 \frac{\text{lbf}}{\text{in}^2}$$

and therefore the maximum pressure the pump can create is 62.4 + 11.5 = 73.9 psi. This is less than the 100 psig set point of the filter vessel relief valve such that the liquid pump cannot over pressurize the filter vessels.

Vapor Compressor

A vapor compressor draws vapor from the main tank and pumps it thru the two filter vessels before it returns to the tank. The vapor compressor is a Senior Aerospace model MB-602 metal bellows compressor. Its manufacturer data is available in the appendix. It is relieved by PSV-361-Ar which is a Circle Seal 5100 series size 2MP relief valve set at 40 psig. The compressor, which is connected in parallel, provides 0.5 SCFM of flow at 40 psig. A Circle Seal 5100 series 2MP provides 5.5 SCFM of relief capacity at 40 psig (data available in the appendix) such that the bellows pump cannot pressurize the filter vessels.

Filter Vessel Vacuum Relief

Each filter vessel is contained within its own insulating vacuum. Vacuum breaks prevent communication between the filter vessel insulating vacuum and the piping insulating vacuum. The parallel plate relief is installed without springs and only 2 of the 4 guide bolts to ensure smooth operation. According to Eden Cryogenics drawing BC-02128-0103 the outside diameter of the parallel plate top plate is 5.5 in², the thickness is 0.5 in, and the material 304 stainless, which has a density of 0.28 lb/in³. The weight of the parallel plate top relief is

$$\frac{\pi}{4}(5.5^2) \text{ in}^2 \times 0.5 \text{ in} \times \frac{0.28 \text{ lb}}{\text{in}^3} = 3.33 \text{ lb}.$$

Eden drawing BC-02128-5875 dimensions the sealing o-ring diameter as 4.137 inches. Thus the force required to lift the top plate is the weight of the plate divided by the internal area against which pressure acts:

$$\frac{3.33 \text{ lb}}{\frac{\pi}{4}(4.137^2) \text{ in}^2} = 0.25 \frac{\text{lb}}{\text{in}^2}.$$

Thus the cracking pressure of the parallel plate relief is 0.25 psi.

According to the CGA S-1.3—2008 5.4, the area of a vacuum relief in sq. in. should be 0.00024 in²/lb of vessel water capacity. The density of water is about 8.34 lb/gal. The vacuum jacket volume is estimated as a cylinder of 24 inch SCH 10 pipe 75 inches tall (the displacement of the inner vessel is ignored).

$$\frac{\pi}{4}(23.5^2) \text{ in}^2 \times 75 \text{ in} \times \frac{1 \text{ gal}}{231 \text{ in}^3} \times \frac{8.34 \text{ lb}}{\text{gal}} = 1,174.5 \text{ lb water capacity}.$$

Thus the required vacuum relief area is

$$0.00024 \frac{\text{in}^2}{\text{lb}} \times 1,174.5 \text{ lb} = 0.28 \text{ in}^2.$$

The parallel plate is sits atop a 3 inch SCH 10 pipe. The vacuum relief flow area is

$$\frac{\pi}{4}(3.26^2) \text{ in}^2 = 8.35 \text{ in}^2$$

which is much larger than the required 0.28 in² such that the vacuum jacket is adequately relieved according to CGA S-1.3—2008 5.4.

Condensation

The saturation temperature that corresponds to the relieving pressure of the liquid argon is 114.3 K. This temperature is above the boiling point of nitrogen (77.4 K) or oxygen (90.2 K) such that condensation of the major components of air will not occur.

At atmospheric pressure carbon dioxide deposits directly to a solid. Air contains about 388 ppm CO₂ by volume. The heat of sublimation of CO₂ is 199,000 J/kg. The density of CO₂ at standard conditions (70 °F & 14.7 psia) is 0.114 lb/ft³. The air flow required to deposit CO₂ on the surface of the liquid argon vessel at a rate equal to the 3,697 W fire case heat load is calculated as follows

$$3,697 \frac{\text{J}}{\text{s}} \times \frac{\text{kg}_{\text{CO}_2}}{199,000 \text{ J}} \times \frac{2.2 \text{ lb}_{\text{CO}_2}}{1 \text{ kg}_{\text{CO}_2}} \times \frac{60 \text{ s}}{\text{min}} \times \frac{\text{ft}^3_{\text{CO}_2}}{0.114 \text{ lb}_{\text{CO}_2}} \times \frac{1 \text{ ft}^3_{\text{air}}}{338 \times 10^{-6} \text{ ft}^3_{\text{CO}_2}} = 63,643 \frac{\text{ft}^3_{\text{air}}}{\text{min}}.$$

It is not possible for 63,643 SCFM of air to flow into the vacuum jacket to provide CO₂ for this rate of sublimation.

The latent heat of condensation for water at 70 °F is 2,455,000 J/kg-K. At 70 °F saturated air contains 0.00109 lb of water per cubic foot of air. Thus to condense the moisture in air at a rate that corresponds to the fire case heat input requires an air flow of

$$3,697 \frac{J}{s} \times \frac{kg_{H_2O}}{2,455,000 J} \times \frac{2.2 lb_{H_2O}}{1 kg_{H_2O}} \times \frac{60 s}{min} \times \frac{ft^3_{air}}{0.001086 lb_{H_2O}} = 183 \frac{ft^3_{air}}{min}.$$

Once the moisture is removed from the air in the 19 ft³ vacuum jacket, there is no mechanism to displace stagnant dry air in the vacuum jacket with a 183 SCFM flow of fresh moist air.

Vent Pressure Drop for PSV-601-Ar and PSV-568-Ar

The relief valves for both filter vessels vent into the room.

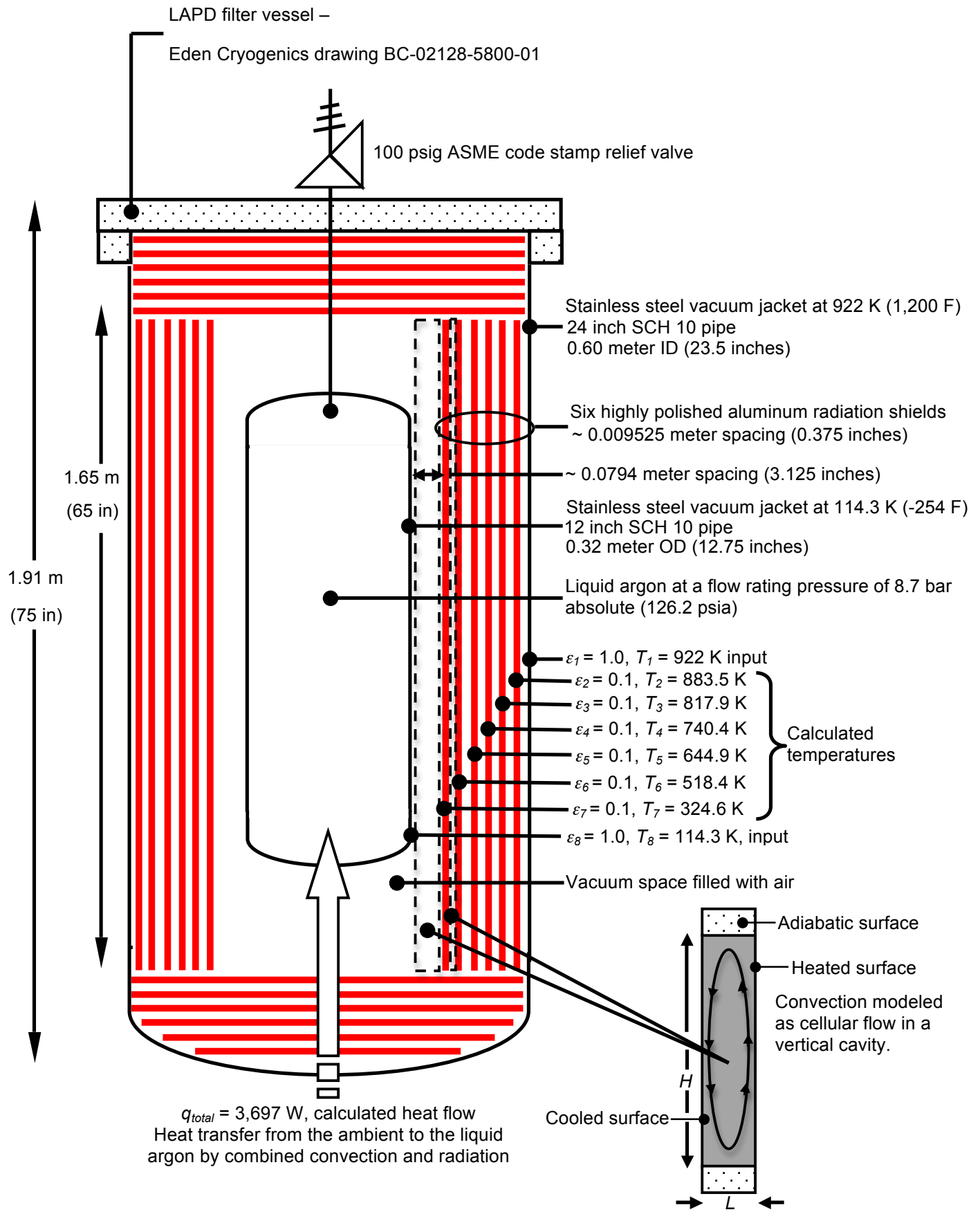


Figure 1: Dimensions, properties, and results for the fire case relief valve calculation.

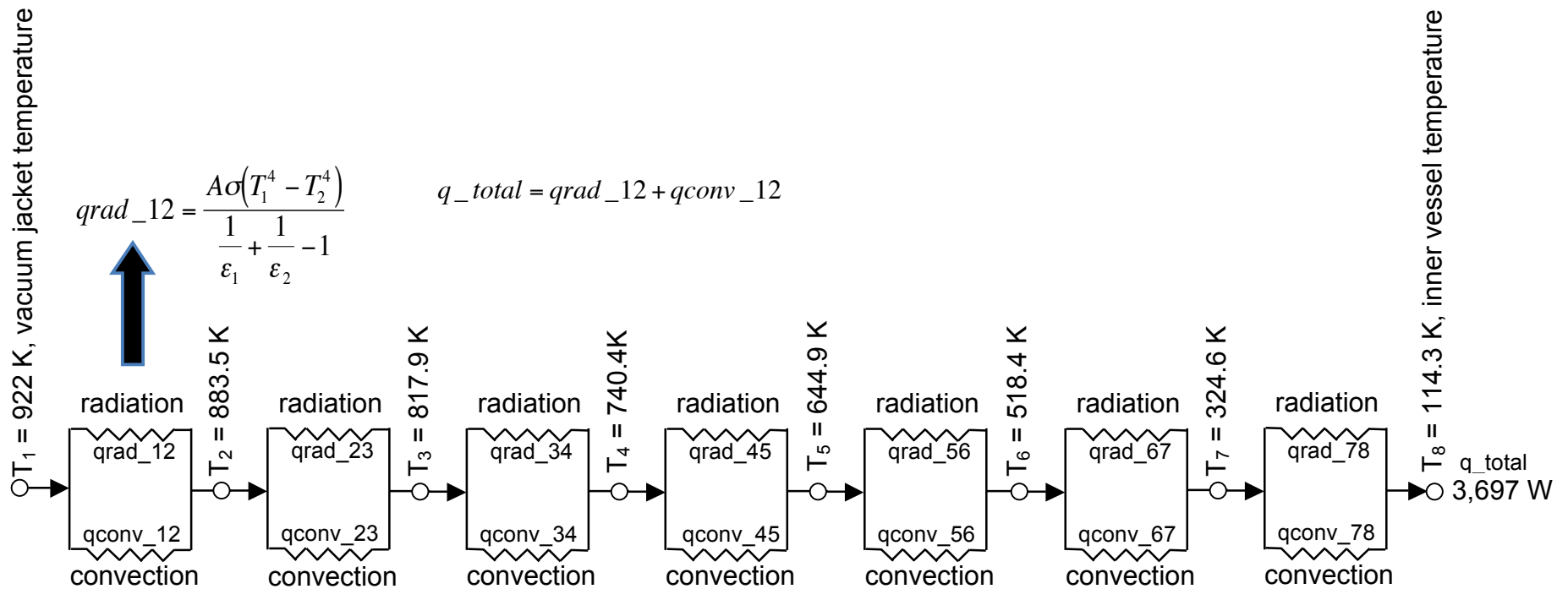
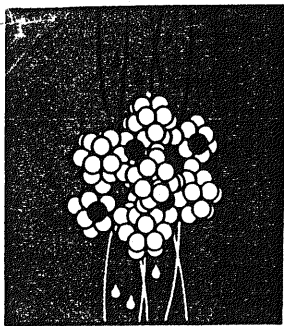


Figure 2: Heat transfer resistance network for the fire case.



UNION CARBIDE MOLECULAR SIEVES

FIXED-BED PRESSURE DROP CALCULATIONS



WORKING EQUATION

The Ergun equation^(a) for the calculation of pressure drop in adsorbent beds is in good agreement with numerous pressure drop measurements made in Union Carbide laboratories and on commercial adsorption units *for both gas phase and liquid phase operation.*

Use the following modified form of the equation to calculate pressure drop through Molecular Sieve beds:

$$\frac{\Delta P}{L} = \frac{f_t C_t G^2}{\rho D_p}$$

where:

C_t = pressure drop coefficient (ft) (sq hr)/(sq in)

D_p = effective particle diameter^(b), ft.

f_t = friction factor

G = superficial mass velocity, lb/(hr) (sq ft)

L = distance from bed entrance, ft. (bed depth)

ΔP = pressure drop, psi

ρ = fluid density, lb/cu ft.

$\Delta P/L$ is the pressure drop per unit length of bed in psi/ft.

The friction factor, f_t is determined from the accompanying graph (page 3) which has f_t plotted as a function of modified Reynold's number.

$$\text{Modified Re} = D_p G / \mu$$

μ = fluid viscosity, lb/(hr) (ft)

[multiply centipoise by 2.42 to obtain lb/(hr) (ft)]

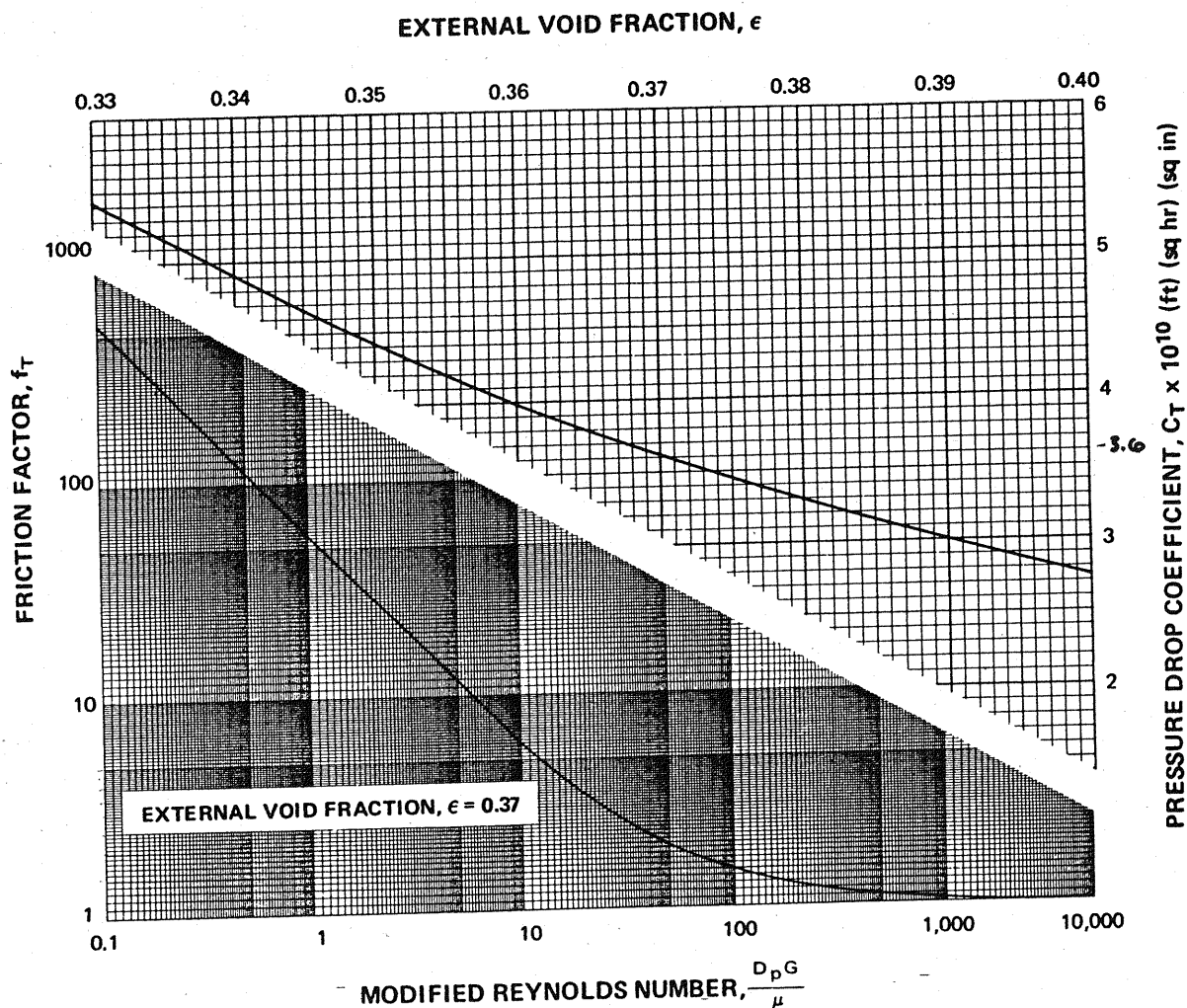
The pressure drop coefficient, C_t , is determined from the graph (page 3) which has C_t plotted as a function of external void fraction, ϵ .

The suggested values for ϵ and D_p for various sizes of LINDE Molecular Sieve are:

	ϵ	D_p
1/8-inch pellets	0.37	0.0122 ft.
1/16-inch pellets	0.37	0.0061 ft.
14x30 mesh granules	0.37	0.0033 ft.

(a) Ergun, S., Chem Engr Prog, 48, 78 (1952)

(b) $D_p = \frac{D_c}{(2/3) + (1/3)(D_c/L_c)}$ where D_c is the particle diameter and L_c is the particle length



EXAMPLE

Determine the pressure drop through an 8 ft. diameter by 10 ft. deep bed of LINDE Molecular Sieve 1/16-inch pellets drying 55 MMSCFD of gas at 50°F and 420 psig. The gas has a molecular weight of 25, a viscosity of 0.010 cp, and a density of 2.0 lb/cu.ft. at operating conditions.

$$G = \frac{55 \times 10^6 \text{ SCFD}}{24 \text{ hrs/day}} \frac{25 \text{ lbs/mol}}{379 \text{ SCF/mol}} \frac{1}{\pi (8)^2 / 4 \text{ sq. ft.}} = 3000 \text{ lb/(hr) (sq.ft.)}$$

$$\text{Modified Re} = D_p G / \mu = \frac{(0.0061) (3000)}{(2.42) (0.010)} = 756$$

$$f_t \text{ (from figure)} = 1.07$$

$$C_t \text{ (from figure for } \epsilon \text{ of 0.37)} = 3.6 \times 10^{-10}$$

$$\frac{\Delta P}{L} = \frac{(1.07) (3.6) (3000)^2 (10^{-10})}{(2.0) (0.0061)} = 0.28 \text{ psi/ft.}$$

For a bed depth of 10 ft.

$$\Delta P = (0.28) (10) = 2.8 \text{ psi}$$

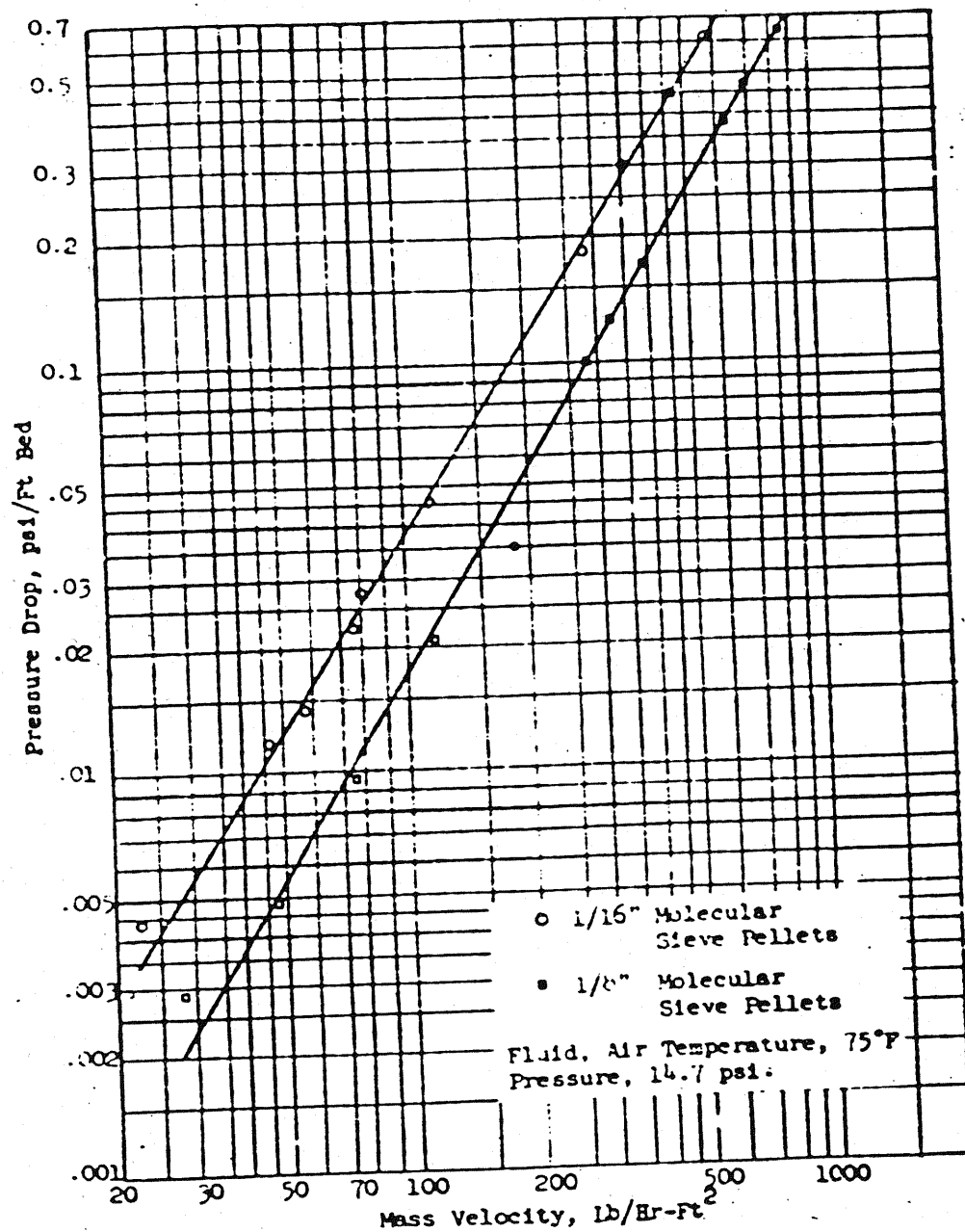


FIGURE 191

PRESSURE DROP THROUGH PACKED COLUMNS
 6 INCHES OR MORE IN DIAMETER
 (COURTESY OF THE LINDE CO.)

fig 1

For flow through a curved pipe or coil, a secondary circulation of fluid called the double-eddy or Dean effect takes place in a plane at right angles to the main flow. Because of this circulation the friction loss in the curved pipe is greater than in an equal length of straight pipe. This circulation also stabilizes laminar flow, thus

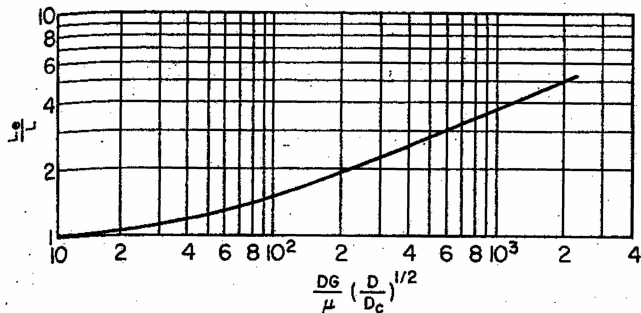


Fig. 5-43. Equivalent length for curved pipe in laminar flow.

[White, *Proc. Roy. Soc. (London)*, A123, 645 (1929).] $\frac{Le}{L} = 1$

for $\frac{DG}{\mu} \left(\frac{D}{D_c}\right)^{1/2} < 10$.

increasing the critical Reynolds number. The maximum Reynolds number, or critical Reynolds number, for laminar flow as a function of pipe diameter and coil diameter is given by Srinivasan, Nandapurkar, and Holland [*Chem. Engr. (London)*, No. 218, CE113-CE119 (May, 1968)]:

$$(N_{Re})_{crit} = 2100 \left(1 + 12 \sqrt{\frac{D}{D_c}} \right) \quad (5-98)$$

for $10 < D_c/D < 250$, where $(N_{Re})_{crit} = (DG/\mu)_{crit}$ = critical Reynolds number, dimensionless; D = pipe diameter, ft.; D_c = coil diameter, ft.; G = mass velocity, lb./ft.²·sec.; μ = fluid viscosity, lb./ft.²·sec.).

Total friction loss for laminar flow in curved pipe can be expressed in terms of an equivalent length L_e of straight pipe. Ratio of the equivalent to actual coil center-line length L_e/L is a function of the Dean number or $N_{Re} \sqrt{D/D_c}$ as shown in Fig. 5-43 (see also Srinivasan *et al.*, *loc. cit.*). This curve is accurate to within ± 5 per cent. A summary of published theoretical work plus their theoretical analysis of pressure drop in laminar flow in a coiled tube

is given by Larrain and Bonilla [*Trans. Soc. Rheology*, 14(2), 135-147 (1970)]. The friction loss for turbulent flow can be computed from the Fanning equation, Eq. (5-52), where for industrial helices the friction factor f_c is given by the empirically determined equation (see Srinivasan *et al.*, *loc. cit.*):

$$f_c = 0.08 N_{Re}^{-0.25} + 0.01 \left(\frac{D}{D_c} \right)^{0.5} \quad (5-99)$$

Equation (5-99) is probably accurate within ± 10 per cent.

The pressure drop for flow in spirals is discussed by Srinivasan *et al.*, *loc. cit.*, and Ali and Seshadri [*Ind. Eng. Chem. Process Design Develop.*, 10, 328-332 (1971)].

Screens. The flow through a screen can be considered as flow through a number of orifices or nozzles in parallel. Thus the pressure drop or head loss across a screen can be computed from an orifice-type equation. The resulting equation for head loss is

$$\Delta h = \left(\frac{n}{C^2} \right) \left(\frac{1 - \alpha^2}{\alpha^2} \right) \left(\frac{V^2}{2g_c} \right) \quad (5-100)$$

where Δh = head loss, ft. of fluid flowing; n = number of screens in series, dimensionless; C = screen discharge coefficient, dimensionless; α = fractional free projected area of screen, dimensionless; V = superficial velocity ahead of screen, ft./sec.; g_c = dimensional constant, 32.17 (lb.)(ft.)/(lb. force)(sec.²). Experimental data [Grootenhuis, *Proc. Inst. Mech. Engrs. (London)*, A168, 837-846 (1954)] indicate that for a series of screens the over-all head loss is directly proportional to the number of screens in series, as given by Eq. (5-100), and is not affected by either the spacing between successive screens or by their orientation with respect to one another.

Screen discharge coefficient C is a function of screen Reynolds number, $N_{Re} = D_s V \rho / \alpha \mu$, where D_s = aperture width, ft.; ρ = fluid density, lb./cu. ft.; μ = fluid viscosity, lb./ft.²·sec.). For plain square-mesh screens, Lapple's plot of C vs. N_{Re} is given in Fig. 5-44 (courtesy of E. I. du Pont de Nemours & Co.). This curve represents most of the data to within ± 20 per cent. Coefficients greater than 1 probably indicate that the effective free area is larger than that of the projected area and that there is partial recovery of head due to the downstream rounding of the wires.

A correlation of over-all frictional losses across plain square-mesh screens and sintered gauzes is given by Grootenhuis (*loc. cit.*). A correlation based on a packed-bed model for plain, twill, and "dutch" weaves is presented by Armour and Cannon [*Am. Inst. Chem. Engrs. J.*, 14, 415-420 (1968)].

Baffles. For segmental baffles, such as tube-bundle baffles in heat exchangers, the over-all friction loss for turbulent flow can be

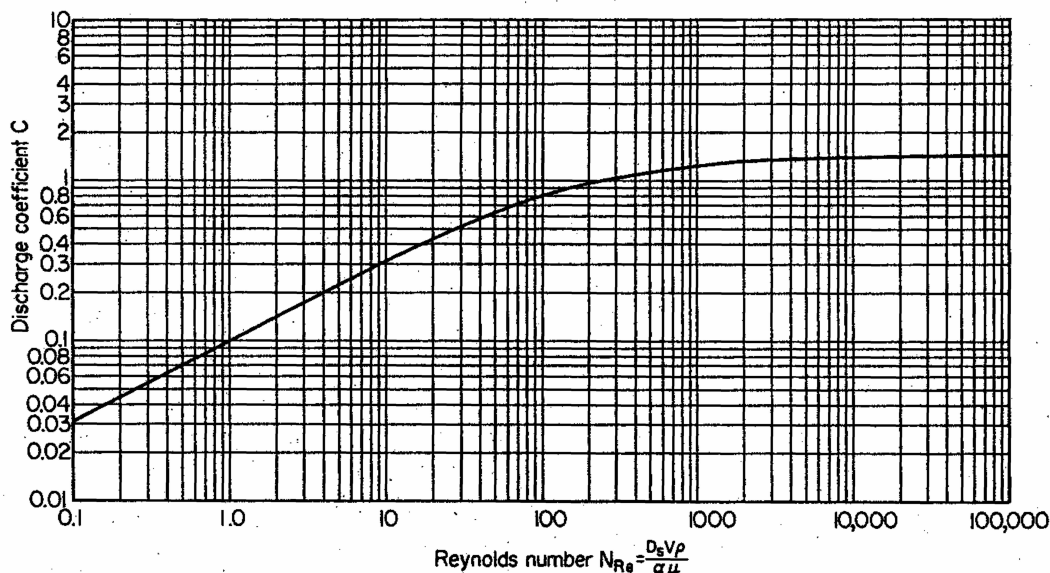


Fig. 5-44. Screen discharge coefficients, plain square-mesh screens. (Courtesy of E. I. du Pont de Nemours & Co.)

TYPE RXSO

0 - 400 psig



A CIRCOR CRYOGENICS COMPANY
**Rockwood
Swendeman**

BRONZE SAFETY RELIEF VALVES

Filter vessel ASME relief mfg info, PSV-568-Ar & PSV-601-Ar,
Also used for PSV-108-HAr

Technical Data

Operating Ranges

Temperature-423°F to +400°F

Set Pressuresto 400 psig

Materials of Construction

ShellCast Bronze,
A.S.M.E SB-62

BaseForged Brass,
Alloy C37700

TrimCopper Alloy

SpringStainless Steel
17-7 PH A.S.T.M.,
A-313, Type 631

Tests

Each valve is set, tested, retested and sealed at the factory to the customer's specifications.

Sizes

Inlet - 1/2 inch to 2 inch

Outlet - 3/4 inch to 2-1/2 inch

Applicable Codes

Designed and manufactured to meet:

- CGA S-1.2 and S-1.3.
- V-4301 (Cryogenic Non-Oxygen)
- V-4401 (Oxygen)
- ASME sec.VIII
- API 527
- AD-Merkblatt A2
- CRN 0G0591.9

Features

- Special Teflon® seat, making bubble-tight seals possible to over 90% of set pressures per spec API 527; not applicable to steam.
- Adjustable blowdown ring
- Meets AD-Merkblatt A2 certified by TÜV
- Cleaned and packaged for use in O₂ service in compliance with the CGA specification G-4.1

Additional cleaning specifications:

- 4WPI-SW70003
- ES.660.503
- GS-38
- GS-40

Application

- Especially recommended where noxious or expensive liquids or gases place a premium on seal quality.
- Stationary Cryogenic storage tanks
- Dual Safety relief systems
- Overpressure relief of tanks, pipelines, vessels, pumps
- Air and gas compressors
- Corrosive industrial applications

Options

- Large and Extra Large Capacity
Consult factory for flow rates
- BSP threads are available on most sizes
- Lever operation

Dimensions & Characteristics

Type RXSO

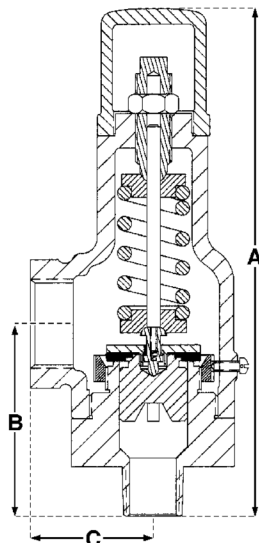
AIR CAPACITY TABLE

Discharge capacities in cubic feet per minute of air at 10% or 3 PSI, whichever is greater, overpressure.

Inlet Sizes Inches	1/2	3/4	1	1-1/4	1-1/2
Outlet Sizes	3/4	1	1-1/4	1-1/2	2
Seat Diameter	A	B	C	D	E
Flow Area	0.118	0.204	0.326	0.424	0.628
Set Pressure					
10	36	63	100	130	193
15	43	74	118	154	227
20	48	85	136	177	262
25	55	96	154	200	297
30	62	108	172	224	332
35	70	120	192	250	370
40	77	133	212	276	408
45	84	145	232	301	446
50	91	157	252	327	485
55	98	170	271	353	523
60	105	182	291	379	561
65	113	195	311	405	599
70	120	207	331	430	638
75	127	220	351	456	676
80	134	232	371	482	714
85	141	244	391	508	752
90	149	257	410	534	791
95	156	269	430	560	829
100	163	282	450	585	867
105	170	294	470	611	905
110	177	307	490	637	944
115	184	319	510	663	982
120	192	331	530	689	1020
125	199	344	549	715	1058
130	206	356	569	740	1097
135	213	369	589	766	1135
140	220	381	609	792	1173
145	228	393	629	818	1211
150	235	406	649	844	1249
155	242	418	668	869	1288
160	249	431	688	895	1326
165	256	443	708	921	1364
170	264	456	728	947	1402
175	271	468	748	973	1441
180	278	480	768	999	1479
185	285	493	788	1024	1517
190	292	505	807	1050	1555
195	299	518	827	1076	1594
200	307	530	847	1102	1632
205	314	543	867	1128	1670

Inlet Sizes Inches	1/2	1/2	3/4	1	1-1/4
Outlet Sizes	3/4	1	1-1/4	1-1/2	2
Seat Diameter	A	B	C	D	E
Flow Area	0.118	0.204	0.326	0.424	0.628
Set Pressure					
210	321	555	887	1153	1708
215	328	567	907	1179	1747
220	335	580	927	1205	1785
225	343	592	946	1231	1823
230	350	605	966	1257	1861
235	357	617	986	1283	1900
240	364	629	1006	1308	1938
245	371	642	1026	1334	1976
250	378	654	1046	1360	2014
255	386	667	1066	1386	2053
260	393	679	1085	1412	2091
265	400	692	1105	1437	2129
270	407	704	1125	1463	2167
275	414	716	1145	1489	2206
280	422	729	1165	1515	2244
285	429	741	1185	1541	2282
290	436	754	1204	1567	2320
295	443	766	1224	1592	2359
300	450	779	1244	1618	2397
305	458	791	1264	1644	2435
310	465	803	1284	1670	2473
315	472	816	1304	1696	2511
320	479	828	1324	1721	2550
325	486	841	1343	1747	2588
330	493	853	1363	1773	2626
335	501	866	1383	1799	2664
340	508	878	1403	1825	2703
345	515	890	1423	1851	2741
350	522	903	1443	1876	2779
355	529	915	1463	1902	2817
360	537	928	1482	1928	2856
365	544	940	1502	1954	2894
370	551	952	1522	1980	2932
375	558	965	1542	2005	2970
380	565	977	1562	2031	3009
385	590	989	1582	2057	3047
390	580	1002	1602	2083	3085
395	587	1015	1621	2109	3123
400	594	1027	1641	2135	3162

DIMENSIONS & WEIGHTS

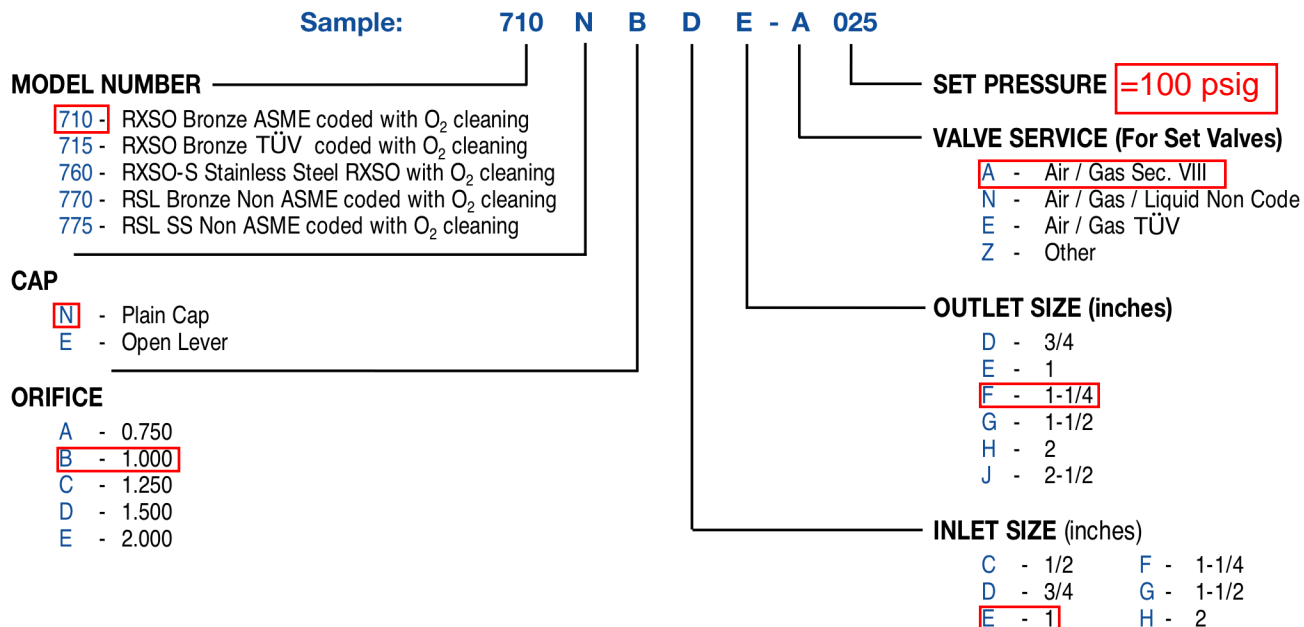


Inlet	Outlet	A	B	C	Weight	Max Psi
1/2	3/4	5 15/16	2 21/32	1 15/16	2 lbs.	max 400 psi
1/2	1	6 9/16	2 29/32	1 9/16	3 lbs.	max 400 psi
3/4	3/4	6 3/16	2 9/16	1 5/16	2 lbs.	max 150 psi
3/4	1	6 9/16	2 29/32	1 9/16	3 lbs.	max 400 psi
1	1	7 23/32	2 15/16	1 5/8	4 lbs.	max 150 psi
1	1 1/4	7 13/16	3 1/2	1 13/16	5 lbs.	max 400 psi
1 1/4	1 1/4	8 23/32	3 1/2	2 9/16	6 lbs.	max 150 psi
1 1/4	1 1/2	9 7/8	3 9/16	2 7/16	7 lbs.	max 400 psi
1 1/2	1 1/2	9 29/32	3 9/16	2 7/16	7 lbs.	max 150 psi
1 1/2	2	10 1/4	3 13/16	2 5/8	9 lbs.	max 400 psi
2	2	10 1/16	3 3/4	2 5/8	9 lbs.	max 150 psi
2	2 1/2	10 1/16	4 1/16	2 13/16	10 lbs.	max 400 psi

TO ORDER: See Page 14

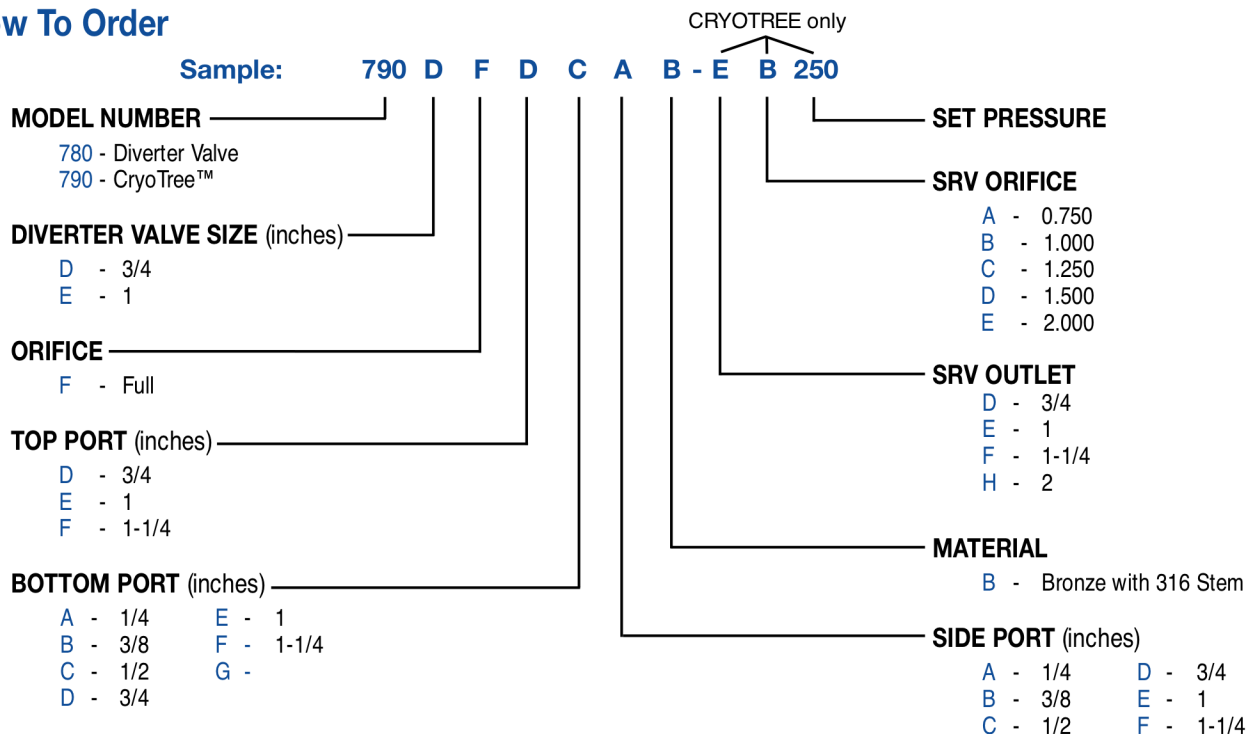
SAFETY RELIEF VALVES

How To Order



DIVERTER AND CRYOTREE™

How To Order



**Model 3200 Series****Single-Stage High-Purity/High Flow Brass and Stainless Steel Regulator****Description**

High-purity regulators for use with high flow rate applications.

Applications

- Applications requiring a high flow rate, such as purging of large reactor or storage vessels.

Design Features/Components

- High-purity nickel plated brass barstock or 316 stainless steel body
- 316 stainless steel diaphragm
- Panel mountable
- Bonnets are ported and threaded to pipe gases away from the work area
- Available as an in-line regulator or a cylinder regulator

Materials of Construction

Body:	316 stainless steel or nickel plated brass barstock
Bonnet:	Stainless steel
Diaphragm:	Teflon lined 316 stainless steel
Seat:	Kel-F 81
Seals:	Teflon

Specifications

	In-Line Regulator	Cylinder Regulator
Maximum Inlet Pressure:	3000 psig (20,700 kPa)	3000 psig (20,700 kPa)
Maximum Flow Rate:	See Table Below*	
Flow Capacity (Cv):	1.0	1.0
Operating Temperature:	-40°F to 165°F (-40°C to 74°C)	-40°F to 165°F (-40°C to 74°C)
Inlet Ports:	1/2" NPT Female	1/2" NPT Female
Outlet Ports:	1/2" NPT Female	1/2" NPT Female
Outlet Connection:	None	1/2" tube fitting
Gauge Ports:	1/4" NPT Female	1/4" NPT Female
Bonnet Vent Port:	1/16" FNPT	1/16" FNPT
Shipping Weight:	4 lbs	5 lbs

* Maximum Flow Rates for In-Line Regulators and Cylinder Regulators (at 2500 psig inlet pressure)

Delivery Pressure	Flow Rate
50 psig	100 SCFM (2832 SLPM)
100 psig	150 SCFM (4248 SLPM)
125 psig	200 SCFM (5664 SLPM)
200 psig	250 SCFM (7080 SLPM)

Ordering Information**In-Line Regulator Models**

Model Number	Delivery Pressure Range	Delivery Pressure Gauge
Stainless Steel Models		
3200	0-50 psig	0-100 psig
3201	0-100 psig	30"-0-200 psig
3203	0-150 psig	30"-0-300 psig
3204	0-250 psig	0-400 psig
Brass Models		
3240	0-50 psig	0-100 psig
3241	0-100 psig	30"-0-200 psig
3243	0-150 psig	0-400 psig
3244	0-250 psig	0-400 psig

Cylinder Regulator Models

Model Number	Delivery Pressure Range	Delivery Pressure Gauge	Cylinder Pressure Gauge
Stainless Steel Models			
3200-CGA	0-50 psig	0-100 psig	0-3000 psig
3201-CGA	0-100 psig	30"-0-200 psig	0-3000 psig
3203-CGA	0-150 psig	30"-0-300 psig	0-3000 psig
3204-CGA	0-250 psig	0-400 psig	0-3000 psig
Brass Models			
3240-CGA	0-50 psig	0-100 psig	0-3000 psig
3241-CGA	0-100 psig	30"-0-200 psig	0-3000 psig
3243-CGA	0-150 psig	0-400 psig	0-3000 psig
3244-CGA	0-250 psig	0-400 psig	0-3000 psig

Available CGA's:

Brass: 320, 346, 580, 590

Stainless Steel: 320, 326, 330, 346, 580, 590, 660, 705

Options

Model Number	Description
63-2233	Inlet Pressure Gauge, 0-3000 psig –
316 Stainless Steel Gauge	For use with Model 3200-3204 Stainless Steel In-Line Regulators
63-3133	Inlet Pressure Gauge, 0-3000 psig –
Chrome Plated Brass Gauge	For use with Model 3240-3244 Brass In-Line Regulators
KIT-0204-SA	Panel Mounting Kit
MSP-0012-XX	Inboard Helium Leak Rate Certification
MSP-0013-XX	Combination Inboard/Outboard Helium Leak Rate Certification

MB-602

SPECIFICATIONS

General

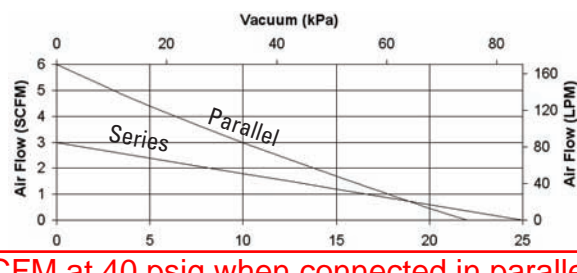
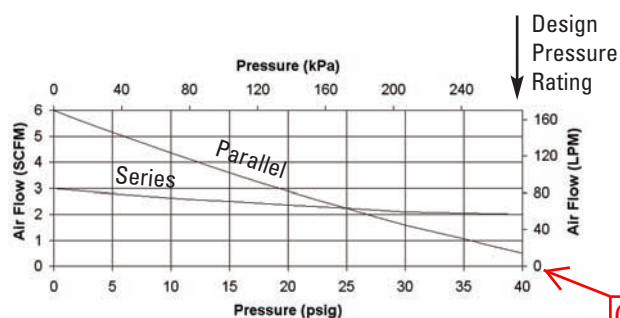
Housing Body	Cast Aluminum
Bellows	AM-350 Stainless Steel
All other wetted surfaces	300 Series Stainless Steel except for Valve Assembly
	Teflon Valve Gaskets and Viton O-Rings
Bearings	Permanently Lubricated Ball Type
Weight	30 lbs
Port Connections	3/8 N.P.T.

Electrical

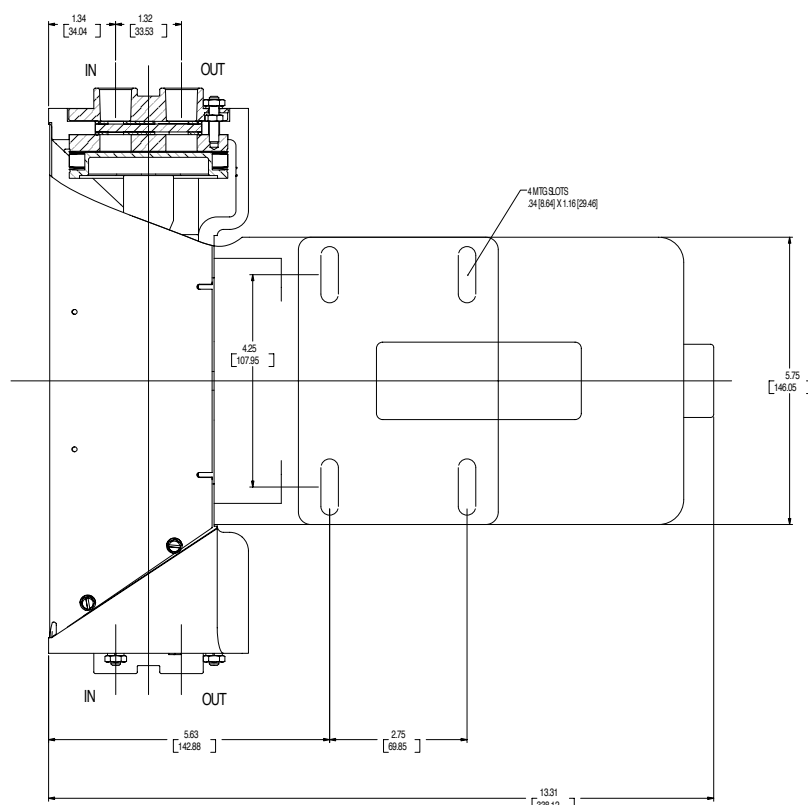
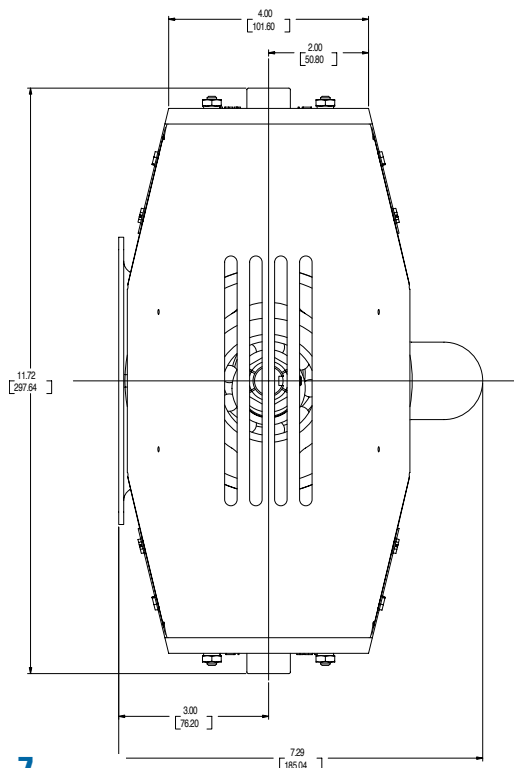
Standard	115/230V 50/60 Hz.
Current at 115V/60 Hz	6.6 Amps (max)
Motor Specification	1/2 H.P. Single Phase
	ODP - Open Drip Proof Motor
Operating Speed @ 60 Hz.	3450 R.P.M.
Insulation	Class B



Optional Features: Explosion Proof Motor, Polyphase Motor, Totally Enclosed Fan Cooled (TEFC) Motor, VCR Fittings, Viton Valve Gaskets

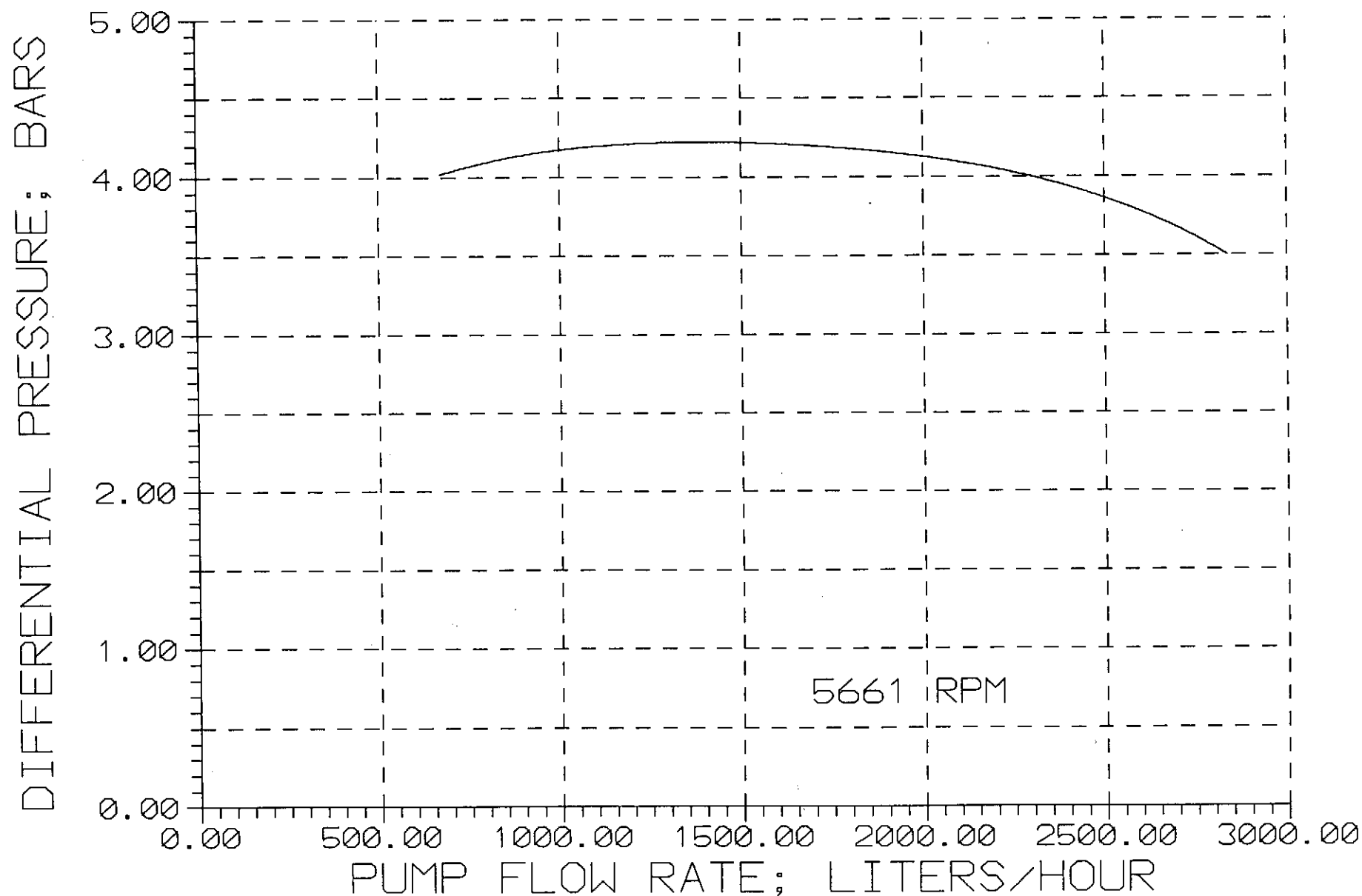


Flows depicted are at 60Hz. Flows at 50 Hz are 5/6 of 60 Hz flows.



This is the pump curve for the liquid argon pump operating at its maximum operating speed.

BNCP-32B LIQUID ARGON PUMP HEAD-FLOW CURVE



5661 RPM

FIGURE 3

5100 Series

Inline Relief Valves

10 to 2400 psig (0.7 – 165 bar)

PSV-361-Ar manufacturer supplied data. PSV-361-Ar prevents the vapor compressor from creating more than 40 psig of pressure.



Features

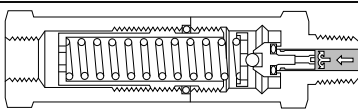
Zero leakage up to 95% of cracking pressure
Positive reseal at high percentage of cracking pressure
Accurate set pressure
Wide range of cracking pressure
Tamper-proof adjustment
PED certifications and CE marking available for most models

Technical Data

Body Construction Materials	Brass, steel, 303 or 316 stainless steel
O-ring Materials	Buna N, ethylene propylene, neoprene, Teflon®, and Viton®
Spring Material	17-7 PH stainless steel
Operating Pressure	0 to 2400 psig (166 bar)
Proof Pressure	3600 psig (248 bar)
Burst Pressure	Over 5000 psig (345 bar)
Temperature Range	–320° F to +400° F (–196° C to +204° F) Based on O-ring material, see "How to Order"
Connection Sizes	½" to 1¼"

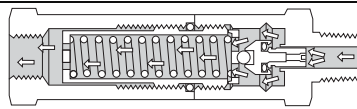
Note: Proper filtration is recommended to prevent damage to sealing surfaces.

How it Works



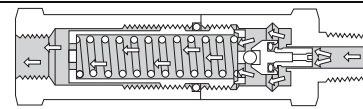
Closed

The spring load is carried by a metal-to-metal stop. The O-ring provides a leak-tight seal. Sealing efficiency increases as the pressure increases up to the cracking pressure.



Cracking

The ports in poppet open fully and eliminate rapid increase in the pressure. The flow is throttled between the poppet shoulder and the seat, which provides regularly increasing flow area with increasing flow rates.



Open

The inline construction and full flow ports permit maximum flow with minimum increase in the system pressure.

relief valves

Circle Seal Controls

2301 Wardlow Circle, Corona, CA 92880
Phone (951) 270-6200 Fax (951) 270-6201
www.circle-seal.com

5100 Series

Cracking Pressure Spring Ranges

Consult your local distributor or the factory for replacement spring part numbers. (Please have your complete valve part number ready when calling.)

Cracking Pressure Ranges (psig)

10–15	82–117	346–450	1201–1400
16–24	118–162	451–575	1401–1900
25–41	163–230	576–710	1901–2400
42–57	231–285	711–999	
58–81	286–345	1000–1200	

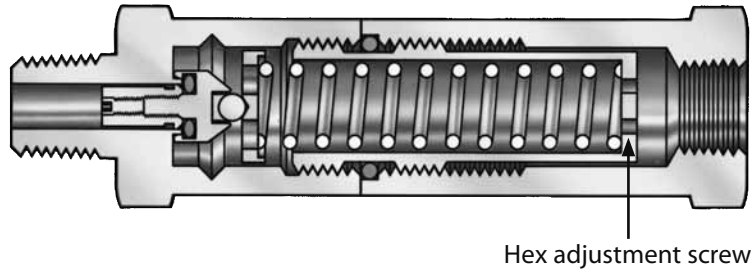
Adjustment

The 5100 Series relief valve is adjustable to $\pm 15\%$ of its nominal cracking pressure as follows:

1. Remove discharge line (in-line mounted unit) or override ring & rod (ASME type)
2. "Break" body joint by wrenching hexes. DO NOT USE PIPE WRENCH.
3. Insert proper size hex wrench (see table below) into the outlet end and turn clockwise to increase the cracking pressure, or counterclockwise to decrease.
4. After adjustment, hold the hex wrench stationary relative to the inlet end and turn the body to tighten the joint.
5. Test adjusted unit for cracking pressure.

Hex Wrench Size

Size	Nominal Cracking Pressure (psig)	
	450 & Under	451 & Over
1/8"	7/32"	7/32"
1/4"	5/16"	1/4"
3/8"	5/16"	1/4"
1/2"	1/2"	3/8"
3/4"	5/8"	1/2"
1"	3/4"	1/2"
1 1/4"	3/4"	3/4"



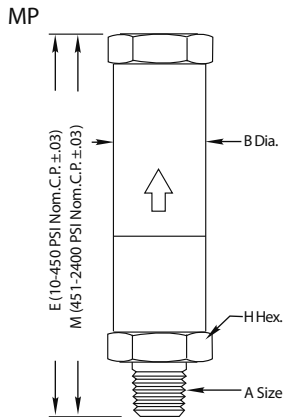
Air Flow Rates (5100–MP)

Inline valves, 1/2"–1"

Crack Pressure PSIG	Percent Over Pressure Beyond Cracking (SCFM air at room temperature)							
	10%				25%			
	1MP	2MP/3MP	4MP	6MP/8MP	1MP	2MP/3MP	4MP	6MP/8MP
15	1.0	1.5	5.0	9.0	3.0	5.0	50	52
20	1.5	2.0	10	12	4.0	5.0	60	63
25	2.0	2.7	25	27	5.4	6.5	65	67
30	2.4	4.6	30	36	6.2	13	68	71
40	3.0	5.5	34	55	6.5	25	72	100
50	3.0	10.5	40	65	8.0	29	74	110
75	4.2	14	50	70	13	38	80	114
100	6.0	25	54	90	17	55	90	130
125	8.5	32	70	120	22	58	110	136
150	10	36	72	150	27	78	115	200
200	13	40	135	190	40	96	250	375
250	16	50	150	210	43	115	280	450
300	20	60	180	225	52	127	400	600
400	25	80	270	270	68	150	600	900
500	36	46	110	190	108	120	320	700
750	45	58	130	210	90	130	420	1200
1000	47	64	170	210	160	160	620	1280
1200	67	74	240	250	200	200	1000	1500
1400	84	84	450	395	—	—	—	—
1600	110	110	720	405	—	—	—	—
1800	160	160	810	510	—	—	—	—
2000	190	190	850	515	—	—	—	—
2200	220	220	900	520	—	—	—	—
2400	240	240	990	675	—	—	—	—

5100 Series

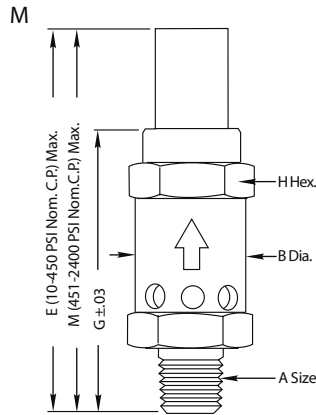
Dimensions (inches)



5100 Series, Inline

Prod. No.	A	E	M	B Dia. H Hex
-1MP	1/8"	2.89	3.49*	0.81*
-2MP	1/4"	3.34	4.24	1.00
-3MP	3/8"	3.36	4.26	1.00
-4MP	1/2"	4.15	5.05	1.25
-6MP	3/4"	5.61	7.11	1.50
-8MP	1"	5.79	7.29*	1.50
-10MP	1 1/4"	7.46	10.22	2.00

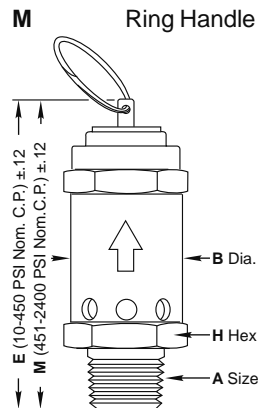
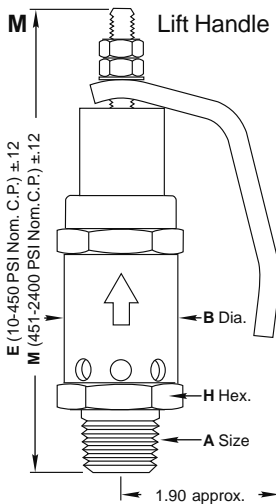
* 1/8" size: for cracking pressure 1201–2400 psig, 'M' is 3.95, 'B' and 'H' are 1.00
 1" size: for cracking pressure 1201–2400 psig, 'M' is 7.32
 1 1/4" size: not available above 1200 psig



5100 Series, Popoff

Prod. No.	A	E	M	G	B Dia. H Hex
-1M	1/8"	2.56	3.16*	2.39*	0.81*
-2M	1/4"	2.87	3.77	2.65	1.00
-3M	3/8"	2.89	3.79	2.74	1.00
-4M	1/2"	3.59	4.49	3.27	1.25
-6M	3/4"	5.00	6.50	4.16	1.50
-8M	1"	5.18	6.68	4.34	1.50
-10M	1 1/4"	6.70	8.65	4.96	2.00

* 1/8" size: for cracking pressure 1201–2400 psig, 'M' is 3.58, 'G' is 2.48, 'B' and 'H' are 1.00
 1 1/4" size: not available above 1200 psig



M5100 Series, Popoff with Manual Override

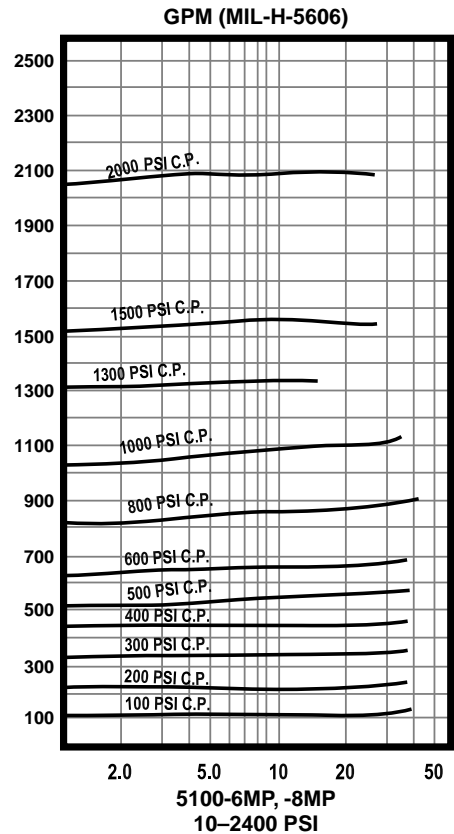
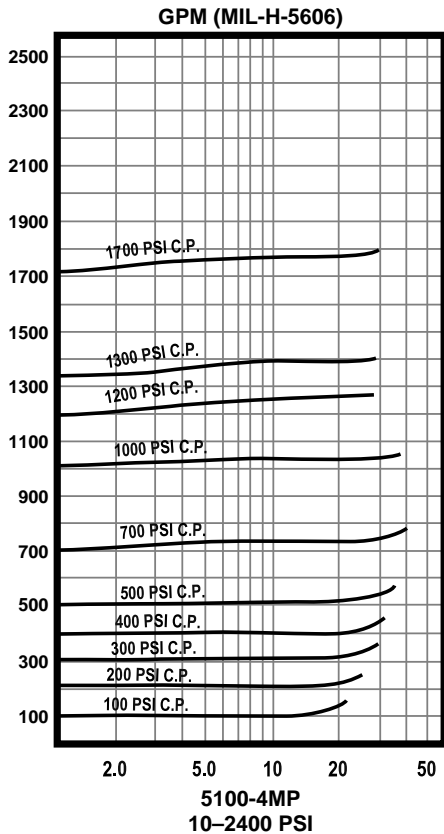
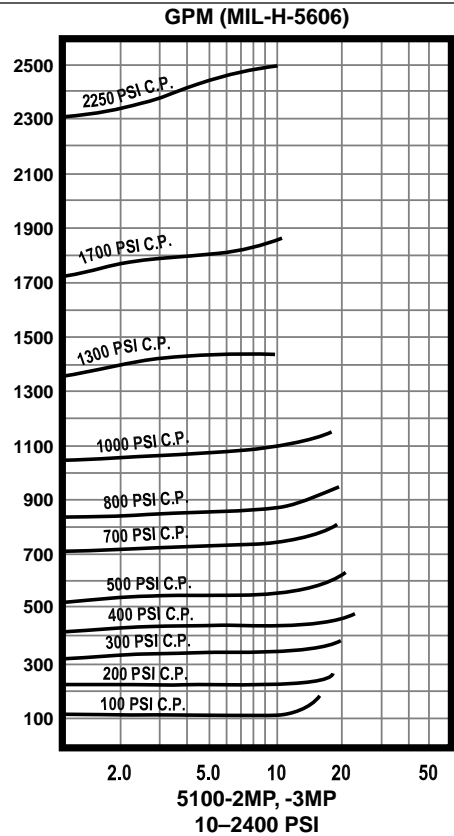
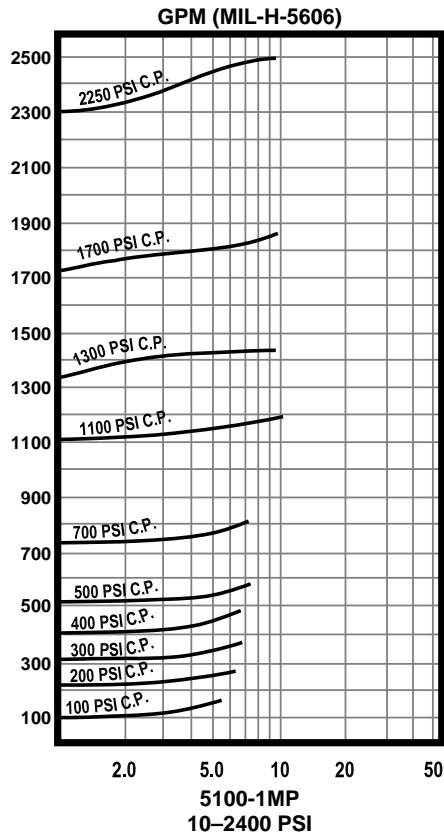
Prod. No.*	A	E	M	B Dia. H Hex
-1M	1/8"	2.84	3.45**	0.81**
-2M	1/4"	3.16	4.06	1.00
-3M	3/8"	3.19	4.09	1.00
-4M	1/2"	3.86	5.51	1.25
-6M	3/4"	5.41	7.54	1.50
-8M	1"	5.59	7.72	1.50
-10M	1 1/4"	6.95	10.42	2.00

* Ring handle is supplied for 1M, 2M, and 3M. For larger sizes, ring handle only supplied for cracking pressure up to 450 psi.

** 1/8" size: for cracking pressure 1201–2400 psig, 'M' is 3.84, 'B' and 'H' are 1.00
 1 1/4" size: not available above 1200 psig

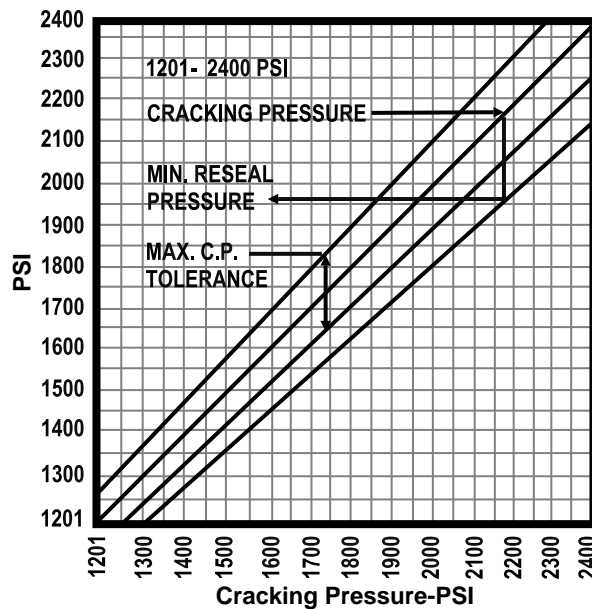
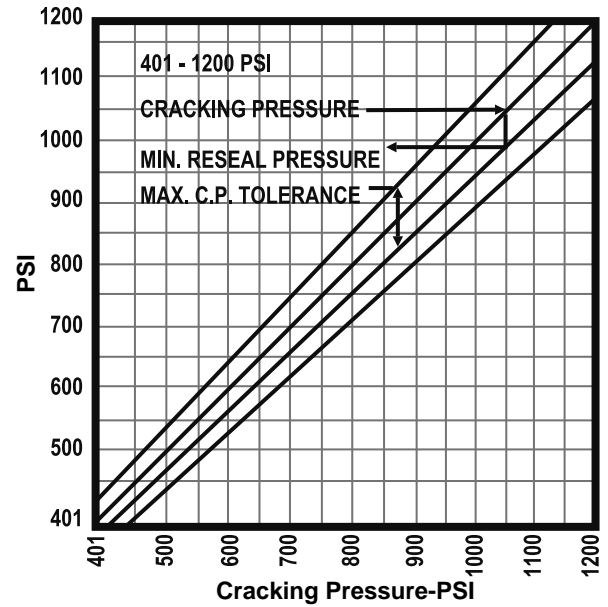
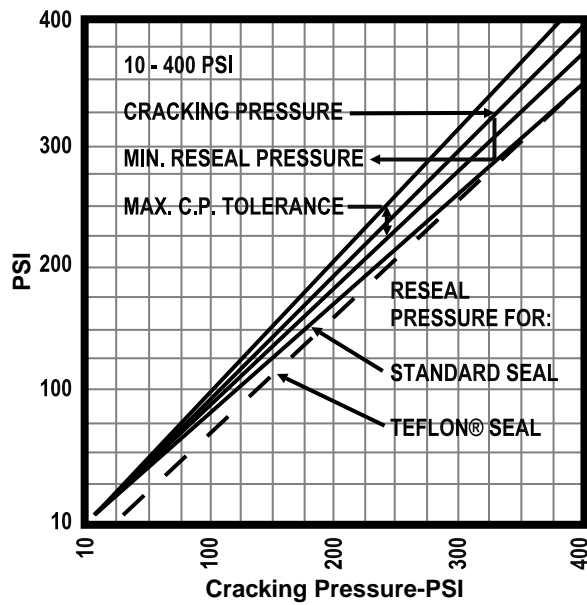
5100 Series

Hydraulic Flow Curves



5100 Series

Cracking & Reseal Pressure



Definitions

1. *Cracking pressure* is defined as 5cc/min with gas (0.2 scfm for 5120 Series)
2. *Reseat point* is the point at which the valve closes, cutting off virtually all flow.
3. The *reseal point* is the point at which the valve seals absolutely tight so that there is no leakage detectable by normal means of measurement.

How to Order

M 51 59 B-2 MP (L) - 20

VARIATION**

K Cryogenic service, special cleaning and testing (stainless steel valves only)

M Manual

O-RING MATERIAL, TEMPERATURE & CRACKING PRESSURE RANGE

20 Teflon®
5120 Series*: -100° to +400° F (-73° to +204°C)
K520 Series: -320° to +165° F (-196° to +74°C)

32 Viton®, -20° to +400° F (-29° to +204°C)

33 Neoprene, -40° to +300° F (-40° to +149°C)

59 Buna N, -65° to +275° F (-54° to +135°C)

62 Ethylene propylene, -65° to +300° F
(-54° to +149°C)

80 Teflon®, -320° to +165° F (-196° to +74°C)

BODY MATERIAL

B Brass^{††}
S Steel[†]
T 303 stainless steel[†]
T1 316 stainless steel

-**CRACKING PRESSURE***

Specify cracking pressure setting in psig
(20 – 2400 psig)

SPECIAL CHARACTERISTICS

L Lockwire
R Resonance dampener (standard for 1201–2400 cracking pressures with elastomeric seals)

CONNECTIONS—INLET/OUTLET

M Male pipe
MP Inline male pipe by female pipe

VALVE SIZE

Pipe sizes in 1/8" increments

1	$\frac{1}{8}"$
2	$\frac{1}{4}"$
3	$\frac{3}{8}"$
4	$\frac{1}{2}"$
6	$\frac{3}{4}"$
8	1"
10	$1\frac{1}{4}"$

* Unit is not rated for liquid cryogenic service below -100°F (-73°C).

** Blank if not required

† Not available for PED applications

†† For PED applications, brass bodies are limited to a maximum temperature use of +100°F (+38°C)

O-rings of Teflon®: Minimum cracking pressure is 20 psi; not available for use above 1200 psi in 3/4" and larger sizes.

To specify PED certification, add PED prefix to the part number.

Repair Kit

In normal service, the only part(s) which may require replacement is(are) the seal(s). A repair kit may be ordered by placing a 'K' in front of the complete part number (i.e. K/5159B-2MP-20).

Please consult your Circle Seal Controls Distributor or our factory for information on special connections, materials, sizes, o-rings, operating pressures and temperature ranges.

Cracking Pressure Tolerance: $\pm 5\%$

Cracking pressures below 20 psig have a tolerance of $\pm 20\%$.

Flow at cracking pressure: Elastomeric seals = 5cc/min

Teflon[®] seals = 0.02 scfm

Reseal pressure***

	<u>Crack Pressure</u>	<u>Reseal Pressures</u>
Elastomeric seals	C.P. > 100 psi C.P. <100 psi	90% of C.P. 70% to 89% of C.P.
Teflon® seals	C.P. > 450 psi C.P. < 450 psi	90% of C.P. 52% to 90% of C.P.

*** The reseal point is the point at which the valve seals absolutely tight so that there is no leakage detectable by normal means of measurement. The point at which the valve closes, cutting off virtually all flow, is called the reseal point. The reseal point is substantially above the reseal.

Leakage at reseal pressure

Elastomeric seals Ascending pressure = zero up to 95% of cracking pressure

Descending pressure = zero at reseal and below

Teflon® seals Ascending pressure = zero up to reseal pressure, then 10cc/min between reseal and cracking pressure

Descending pressure = zero at reseal, except with cracking pressure below 451 psi, then 1cc/min maximum

First crack pressure after standing unactuated for a prolonged period

Set pressure of...	5–19 psi	125% of cracking pressure
	20–29 psi	120% of cracking pressure
	30–49 psi	115% of cracking pressure
	50 psi and higher	110% of cracking pressure



Eden Cryogenics LLC
8449 Rausch Drive
Plain City, Ohio 43064

**Certification of Material, Testing, and Cleaning:
Documentation and Conformance**

Customer FERMI RESEARCH ALLIANCE, LLC	Purchase Order No. 588593	Eden Cryogenics W.O. No. BC-02128
Equipment Description: Liquid Argon TPC Purity Demo Purifier Vessel Part No. BC-02128-5800-01		

This document certifies that Eden Cryogenics, LLC has performed and or verified the noted tests and materials. Testing and materials meet or exceed the requirements of the noted purchase order.

CERTIFICATION OF MATERIALS

<input checked="" type="checkbox"/> All materials for valves / piping / equipment are new and unused.
Verifiable chemical and physical mill certification is <input checked="" type="checkbox"/> Enclosed <input type="checkbox"/> On file at Eden Cryogenics
Materials: _____

<input type="checkbox"/> Soft goods have batch lot numbers and cure dates <input type="checkbox"/> Enclosed <input type="checkbox"/> On file at Eden Cryogenics

CERTIFICATION OF TESTS

<input checked="" type="checkbox"/> Pressure tested <input checked="" type="checkbox"/> Pneumatic <input type="checkbox"/> Hydrostatic @ <u>188</u> PSIG (Inner Vessel)
<input type="checkbox"/> Valves pressure tested across the seat @ _____ PSIG
<input checked="" type="checkbox"/> <u>5</u> % of all butt weld joints radiographed for Work Order
<input type="checkbox"/> Reader sheets enclosed <input type="checkbox"/> Radiographs enclosed <input checked="" type="checkbox"/> Documentation on file at Eden Cryogenics
<input checked="" type="checkbox"/> Mass spectrometer leak tested at 1x10-9 scc/sec helium with no leaks, (Outer Vessel)
<input type="checkbox"/> Other tests: <input type="checkbox"/> LN2 cold shock test <input type="checkbox"/> Other
<input type="checkbox"/> Other

CLEANING

<input type="checkbox"/> Commercially cleaned <input checked="" type="checkbox"/> Commercially oxygen cleaned <input type="checkbox"/> Particulate cleaned
Cleaning specification: _____

Eden Cryogenics, LLC certifies the noted documentation and performance testing.

Project Manager *[Signature]* Date 06/30/10
Quality Control *Randy Basham LTT* Date 6/30/10

Table on Contents

Section 1: Drawings

Section 2: Material Certification

Section 3: Material C of C's

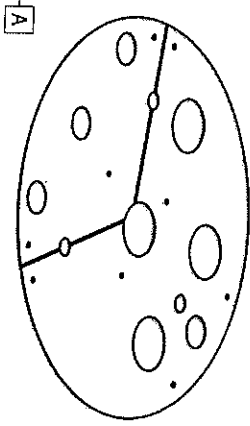
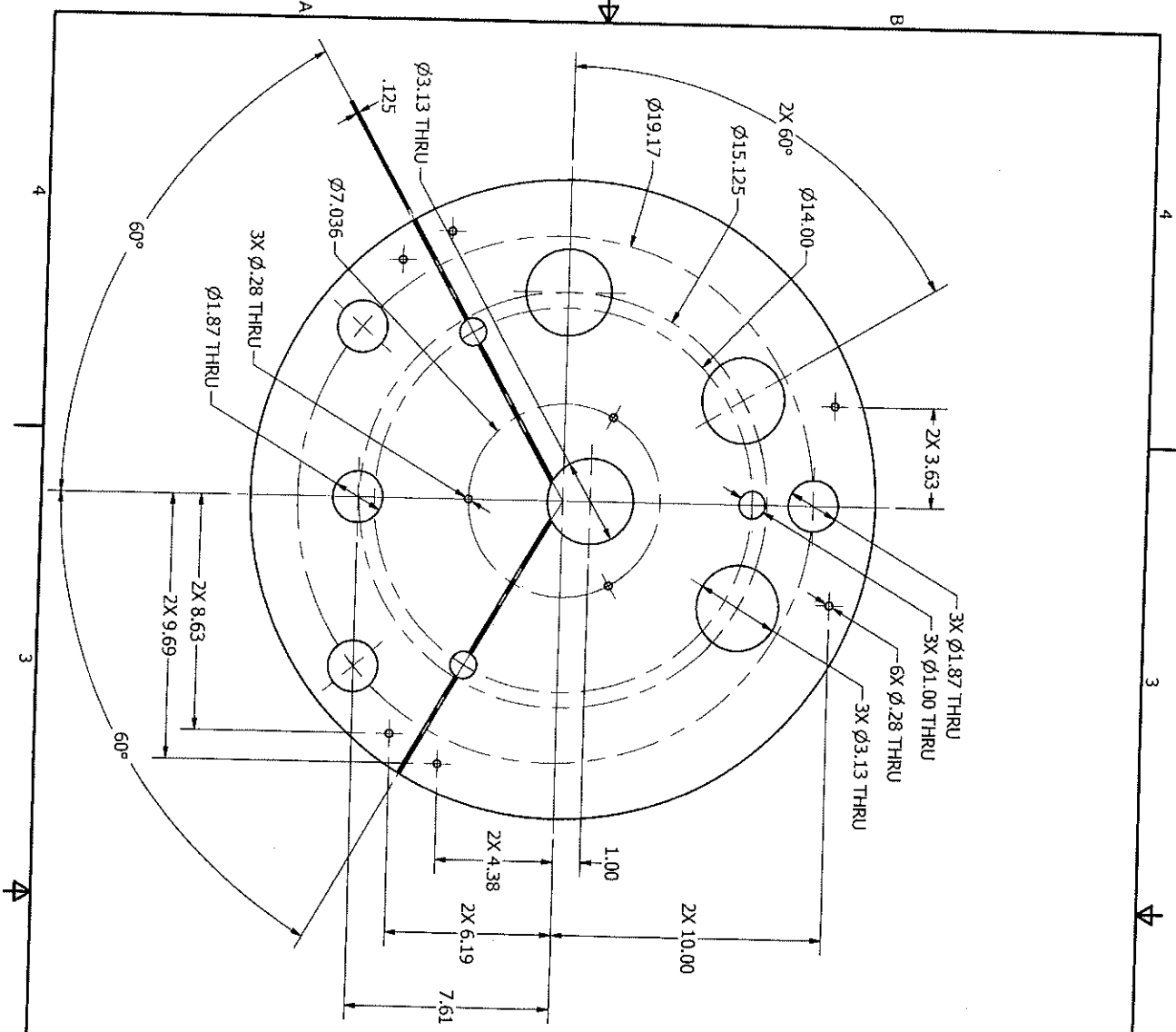
Section 4: Welder Certification

Section 5: Inner Vessel Code Calculations

Section 6: Outer Vessel Code Calculations

Section 7: Test Reports





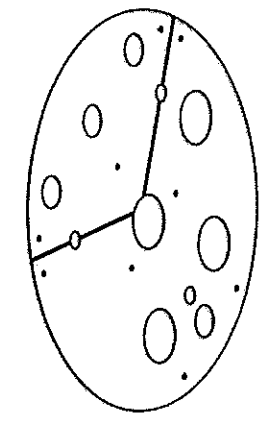
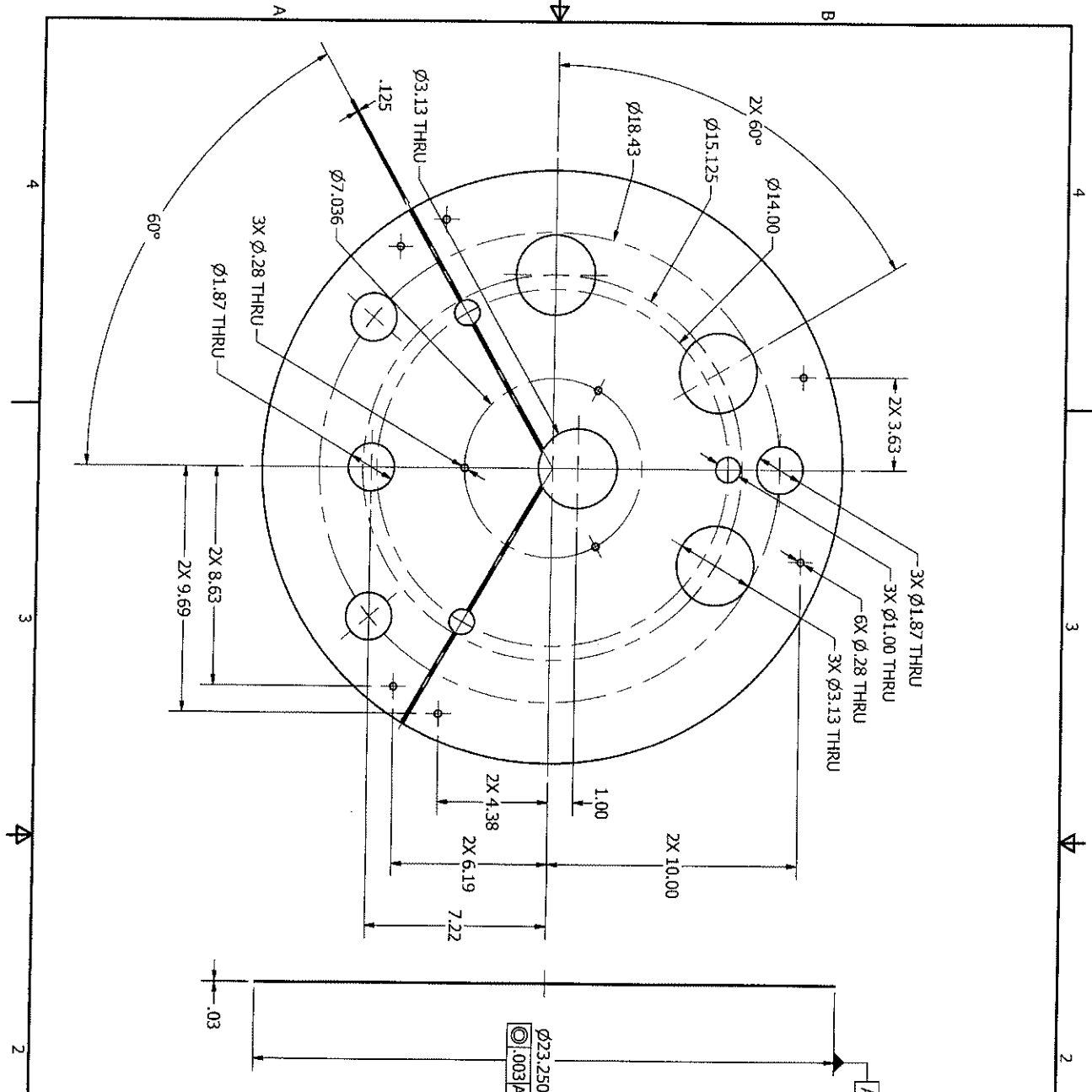
NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 23 1/4 ϕ X 1/32 THK ALUMINUM-6061 ASTM B209

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 32 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencycogenics.com		DWN: MAS 11/30/2009 CHKD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:4	
SIZE: B DRAWING/PART NUMBER: BC-02128-0011	SHEET: 1 OF 1 REV: -	ZONE: - REV: - DATE: - CHANGED BY: - EDR: -	TITLE: BC-02128 TOP HEAT SHIELD		



SCALE 1 : 7

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 23 1/4 X 1/32 THK Aluminum-6061 ASTM B209 T4 TEMPER

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN ORTHOGONICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN ORTHOGONICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH.		X.X ± .030		DWG: MAB 11/30/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XX ± .010		CHKD: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		X.XXX ± .005		ENGR: JHM 12/28/2009	
		ANGULAR ± 1/2°		APP: _____	
				EDR: 09-0377	
				DATE: 12/28/2009	
				SCALE: 1:1	

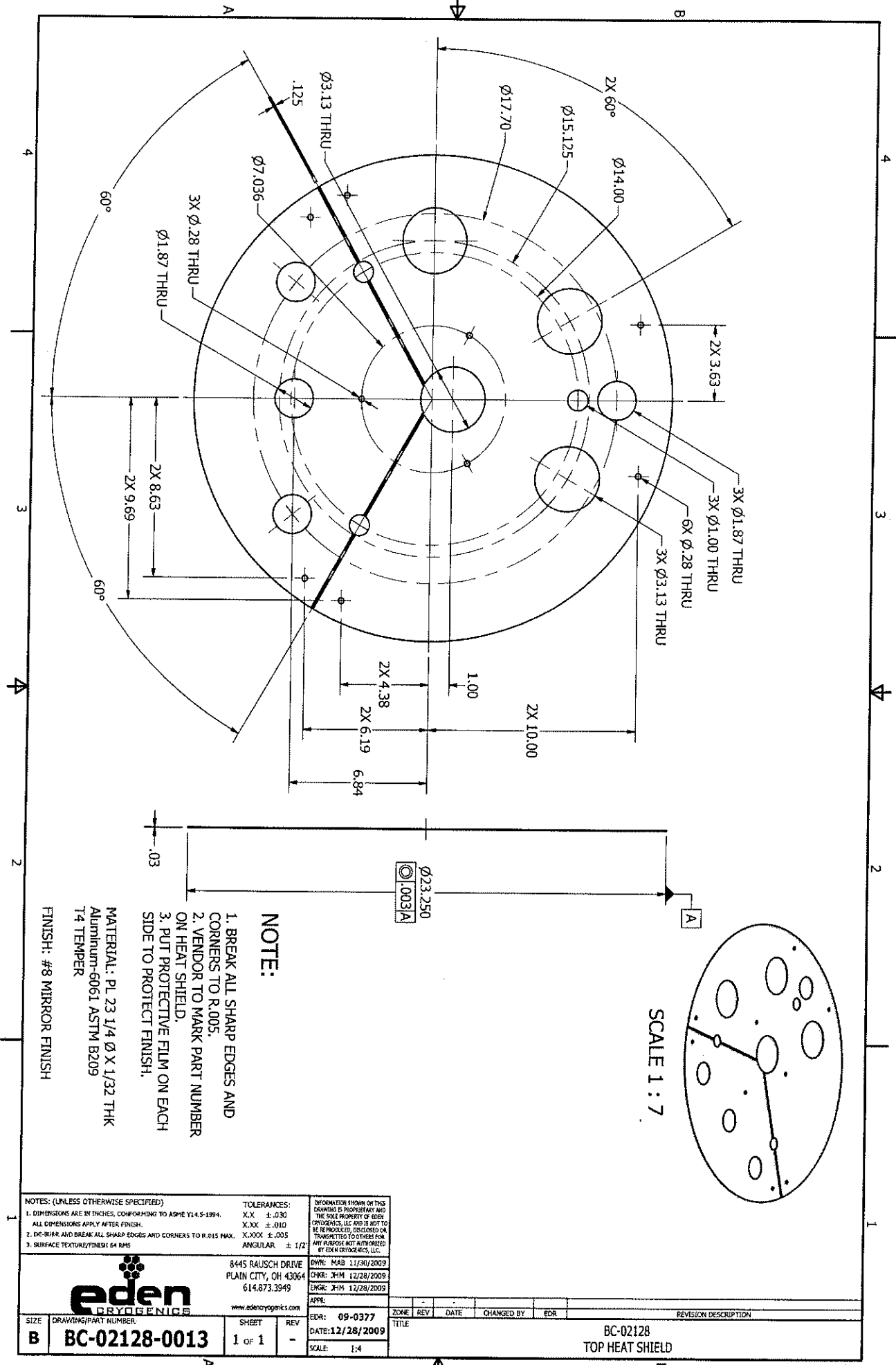


8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.873.3949
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SIZE B	DRAWING/PART NUMBER BC-02128-0012	SHEET 1 of 1	REV -	ZONE -	REV -	DATE 12/28/2009	CHANGED BY EDR	REVISION DESCRIPTION
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BC-02128
TOP HEAT SHIELD

Information Copy



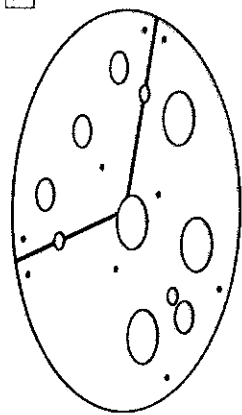
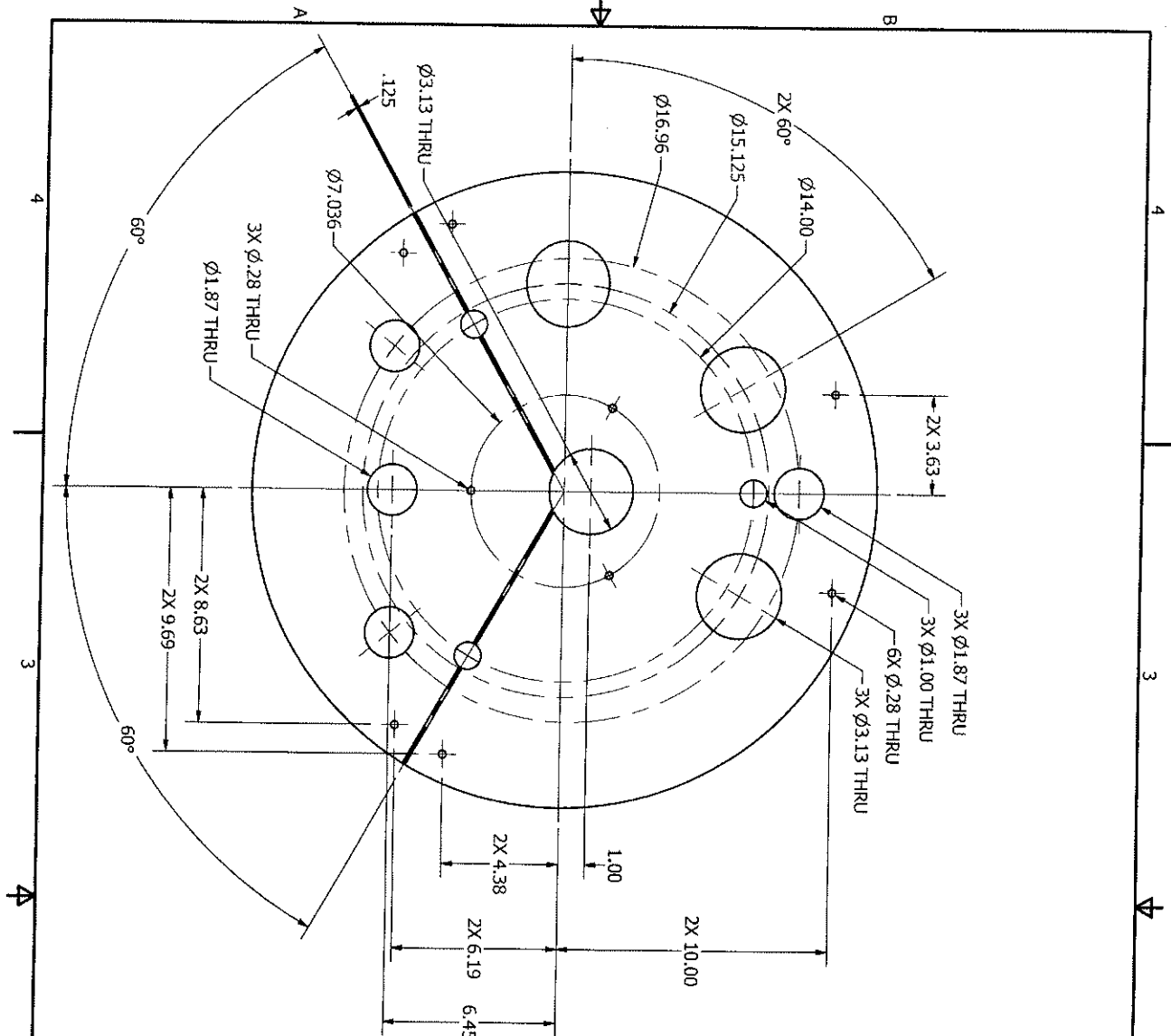
NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, COPIED, OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X	$\pm .030$	DATE: 09-0377	ZONE
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XX	$\pm .010$	DATE: 12/28/2009	REV
3. SURFACE TEXTURE/FINISH: 64 RMS		X.XXX	$\pm .005$	SCALE: 1:4	DATE
		ANGULAR	$\pm 1/2$		CHANGED BY
					EDR
					REVISION DESCRIPTION



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SIZE	DRAWING/PART NUMBER	SHEET	REV	EDR	DATE	SCALE	TITLE
B	BC-02128-0013	1 OF 1	-	09-0377	12/28/2009	1:4	BC-02128 TOP HEAT SHIELD

Information Copy



SCALE 1 : 7

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 23 1/4 Ø X 1/32 THK
Aluminum-6061 ASTM B209
T4 TEMPER

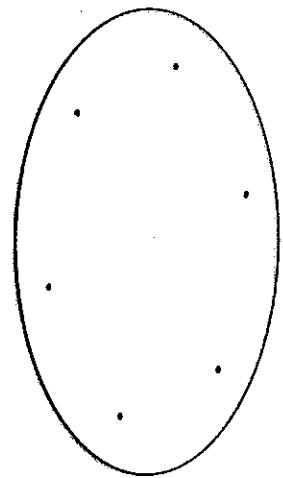
FINISH: #8 MIRROR FINISH

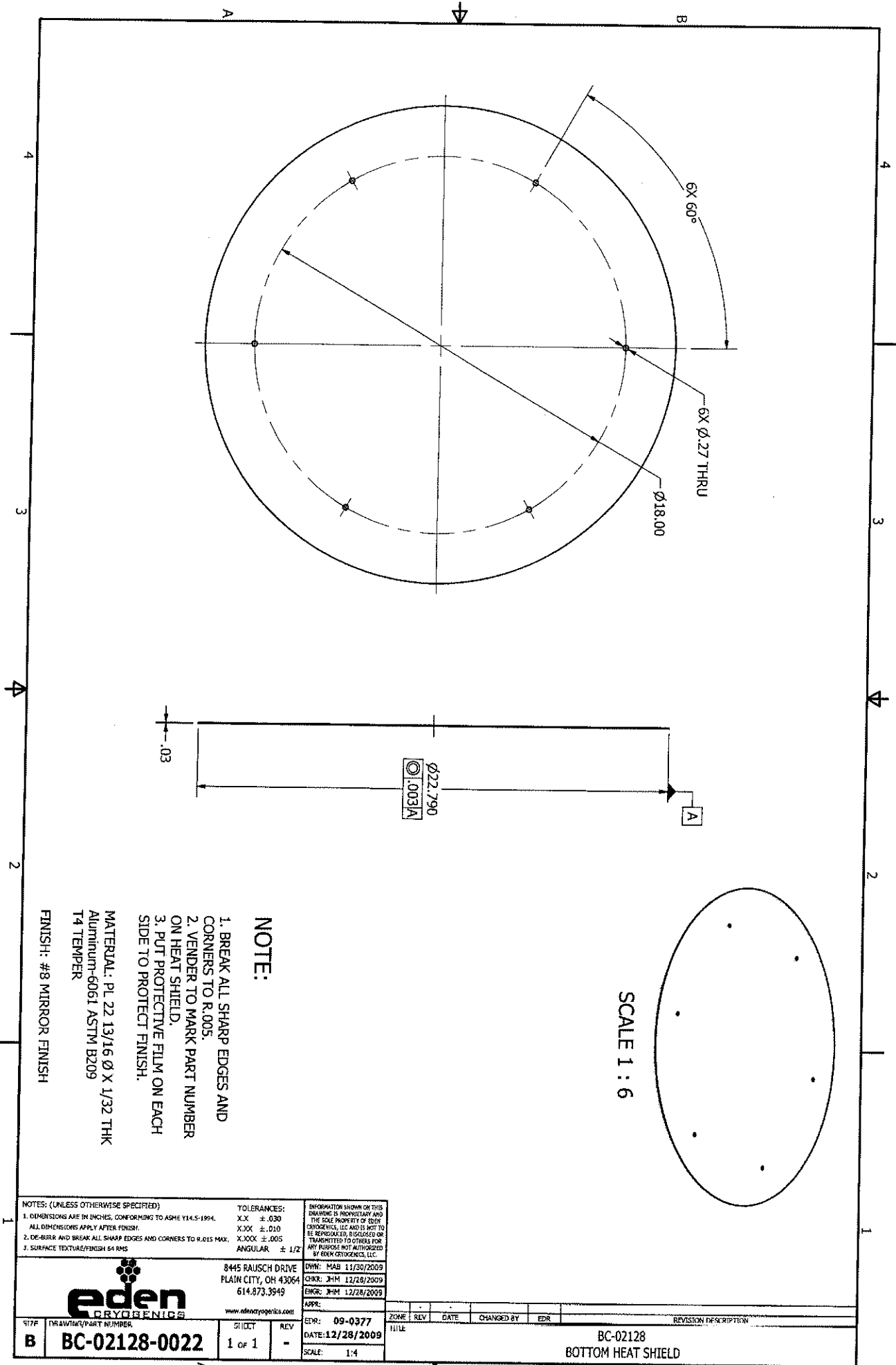
NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BUR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC. DWS: MAB 11/30/2009 CHK: JHM 12/28/2009 ENGR: JHM 12/28/2009 APP:	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 WWW.EDENCRYOGENICS.COM		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:4			

SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
B	BC-02128-0014	1 OF 1	-						

BC-02128
TOP HEAT SHIELD

Information Copy





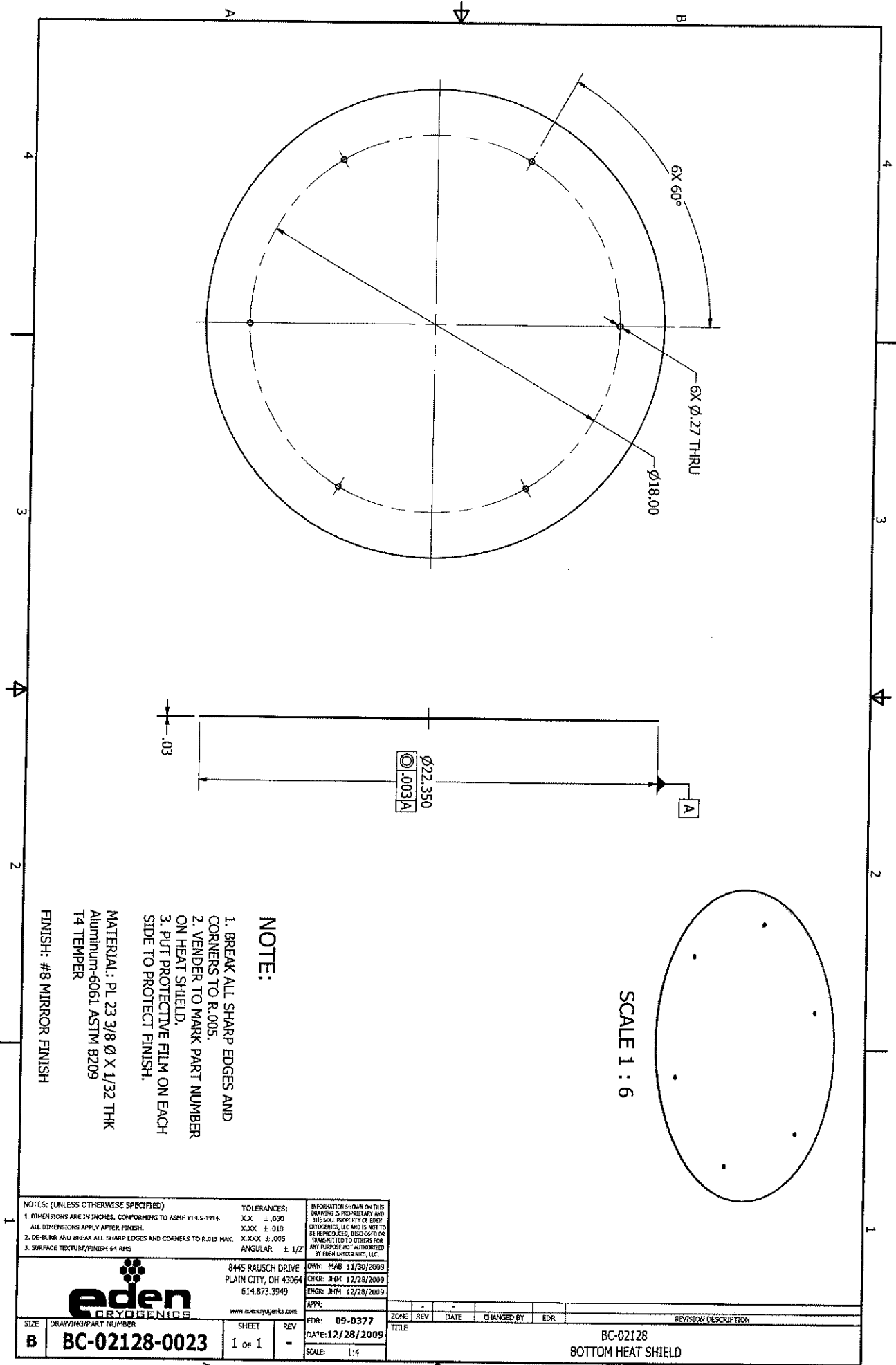
NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 22 13/16 Ø X 1/32 THK
 Aluminum-6061 ASTM B209
 T4 TEMPER

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DWN: MAB 11/30/2009 CHKR: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		DATE: 09-0377 DATE: 12/28/2009 SCALE: 1:4	
517F B	DRAWING/PART NUMBER BC-02128-0022	510CT 1 OF 1	REV -	ZONE REV DATE CHANGED BY EDR TITLE BC-02128 BOTTOM HEAT SHIELD	



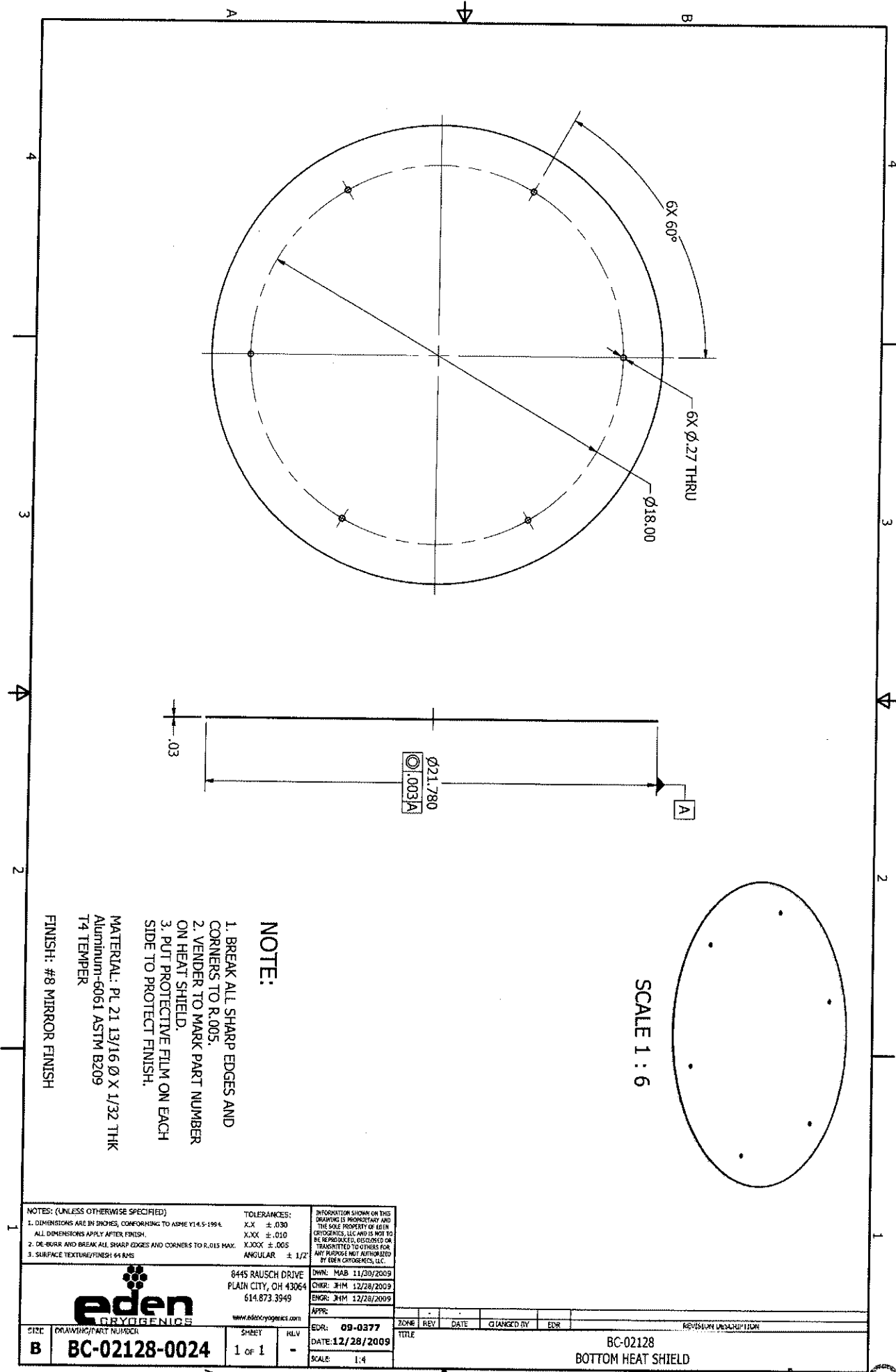
NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 23 3/8 Ø X 1/32 THK Aluminum-6061 ASTM B209 T4 TEMPER

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH: 64 RMS		TOLERANCES: XX ± .030 XXX ± .010 XXXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.673.3949 www.edencyogenics.com		DWN: MAB 11/30/2009 CHGR: JHM 12/28/2009 ENGR: JHM 12/28/2009		APPR:	
SIZE B	DRAWING/PART NUMBER BC-02128-0023	SHEET 1 of 1	REV -	FTR: 09-0377 DATE: 12/28/2009 SCALE: 1:4	TITLE BC-02128 BOTTOM HEAT SHIELD



SCALE 1 : 6

NOTE:

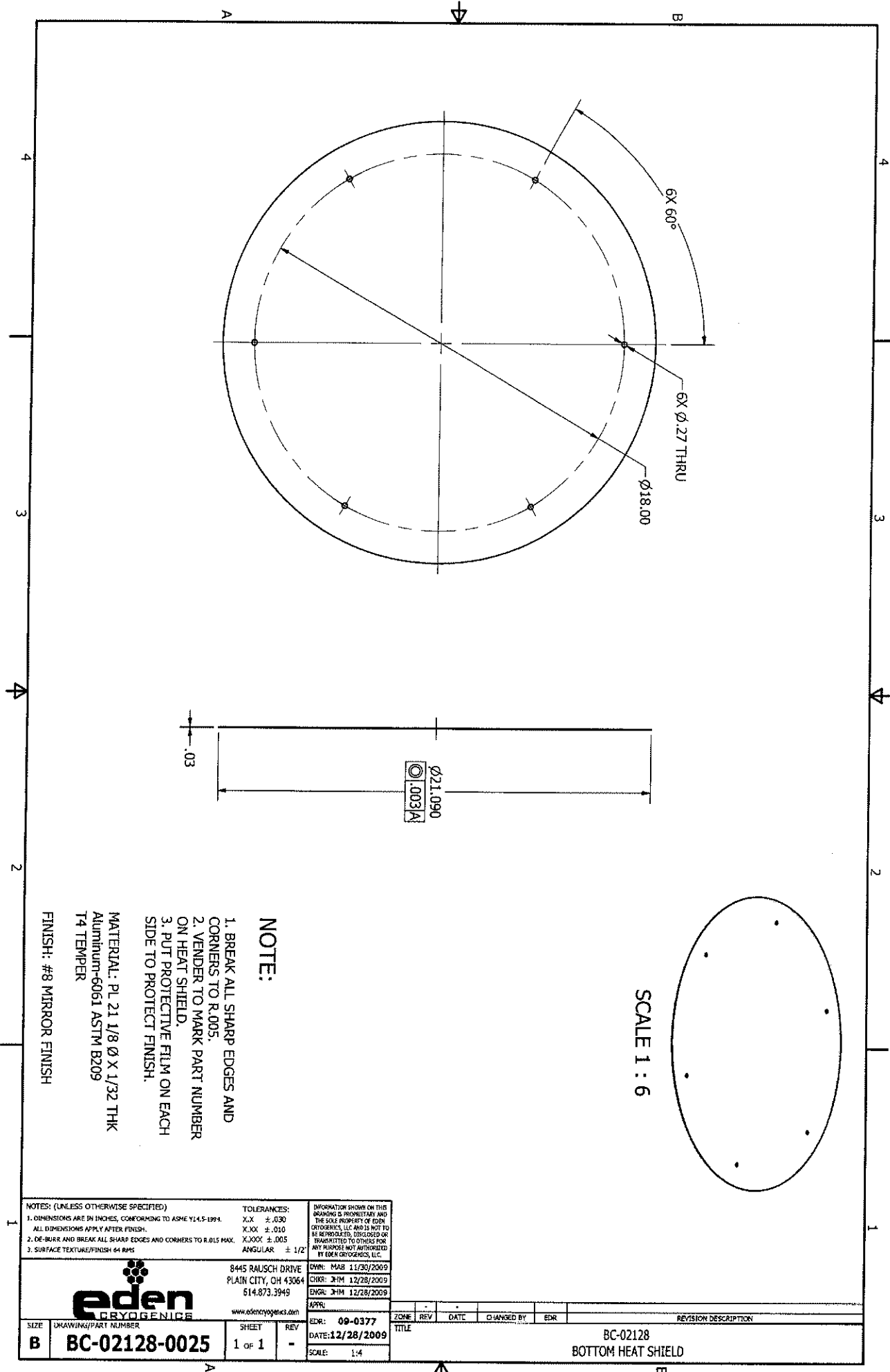
1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 21 13/16 ϕ X 1/32 THK
 Aluminum-6061 ASTM B209
 T4 TEMPER

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH: 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.													
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.eden-cryogenics.com		DWN: MAB 11/30/2009 CHR: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		BC-02128 BOTTOM HEAT SHIELD													
SIZE B	DRAWING/PART NUMBER BC-02128-0024	SHEET 1 OF 1	KLV -	EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:4	<table border="1"> <thead> <tr> <th>ZONE</th> <th>REV</th> <th>DATE</th> <th>CHANGED BY</th> <th>EDR</th> <th>REVISION DESCRIPTION</th> </tr> </thead> <tbody> <tr> <td colspan="6"> </td> </tr> </tbody> </table>	ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION						
ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION												

Information Copy




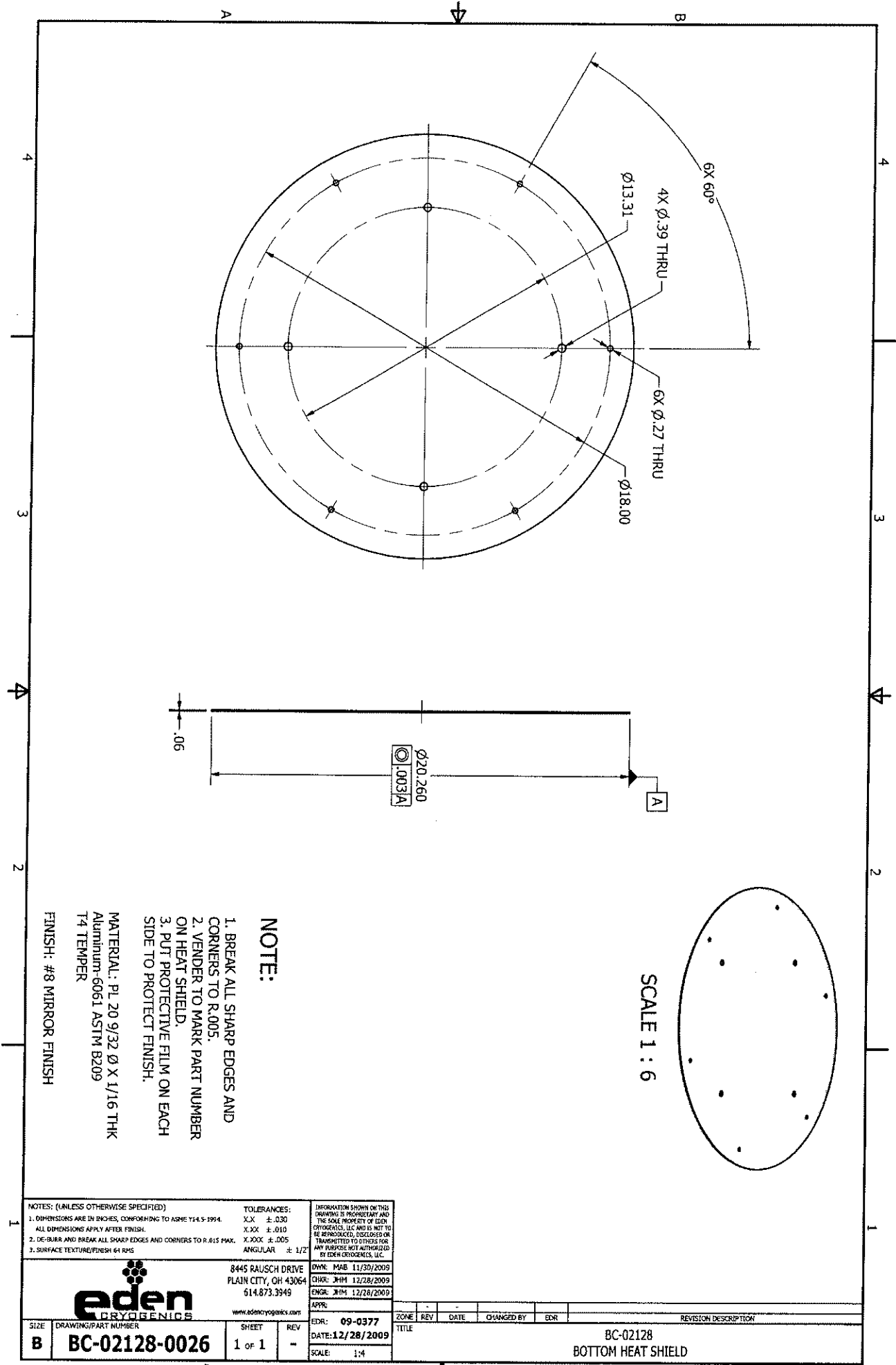
NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 21 1/8 Ø X 1/32 THK
 Aluminum-6061 ASTM B209
 T4 TEMPER

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED)			TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.				
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH.			X.X ± .030 X.XX ± .010 X.XXX ± .005						
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.			ANGULAR ± 1/2°						
3. SURFACE TEXTURE/FINISH 64 RMS									
 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 514.873.3949 www.edencyogenics.com			DWN: MAB 11/30/2009						
			CHK: JHM 12/28/2009						
			ENGR: JHM 12/28/2009						
			APPR:						
			EDR: 09-0377						
			DATE: 12/28/2009						
			SCALE: 1:4						



NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELD.
3. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.

MATERIAL: PL 20 9/32 ϕ X 1/16 THK Aluminum-6061 ASTM B209 T4 TEMPER

FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.XX \pm .030 X.XX \pm .010 X.XXX \pm .005 ANGULAR \pm 1/2		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DWN: MAB 11/30/2009 CHKD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		REVISION DESCRIPTION BC-02128 BOTTOM HEAT SHIELD	
SIZE: B DRAWING/PART NUMBER: BC-02128-0026	SHEET: 1 of 1 REV: -	EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:4		TITLE:	

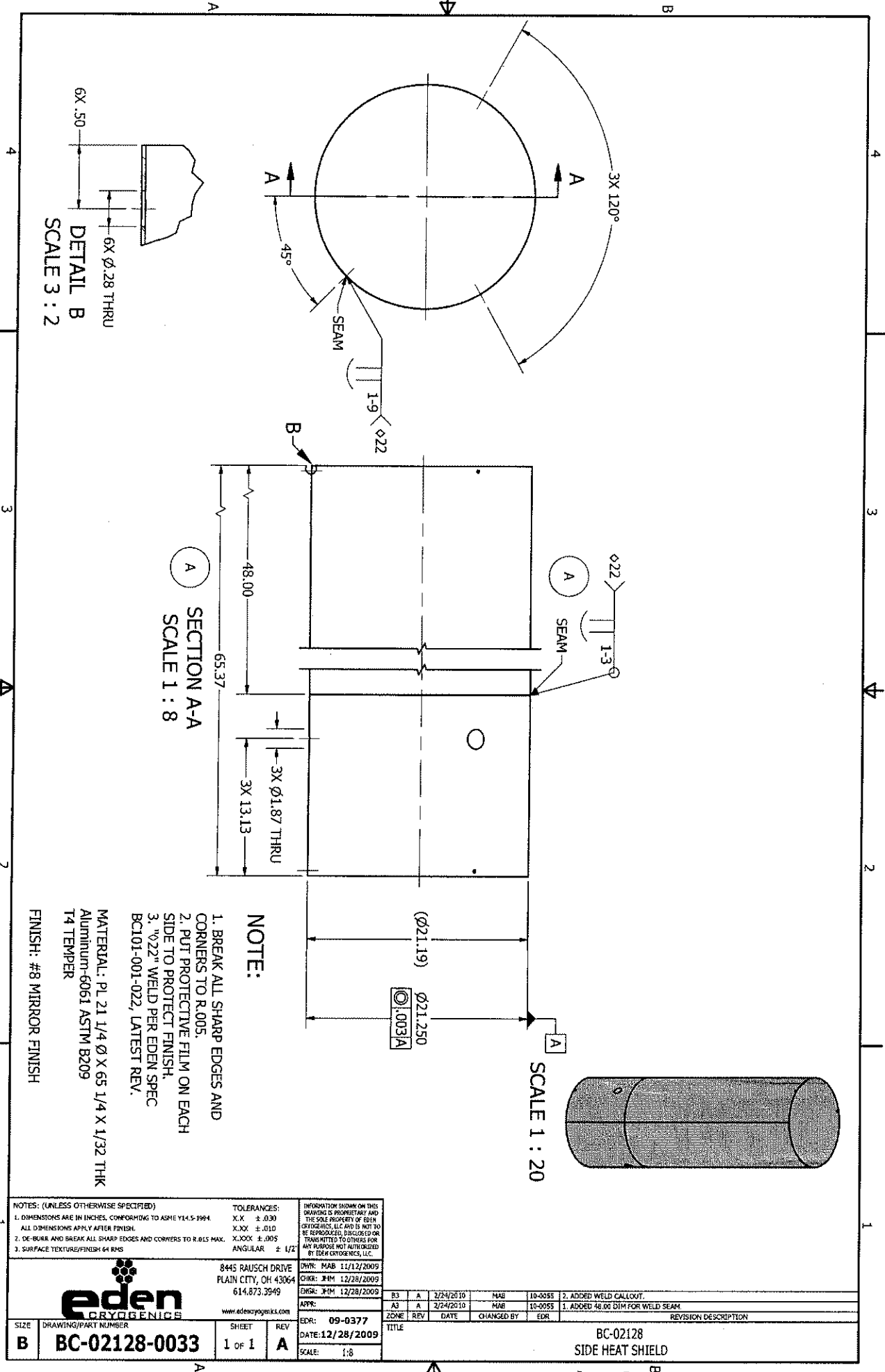
Information Copy




1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.
3. "022" WELD PER EDEN SPEC BC101-001-022, LATEST REV.

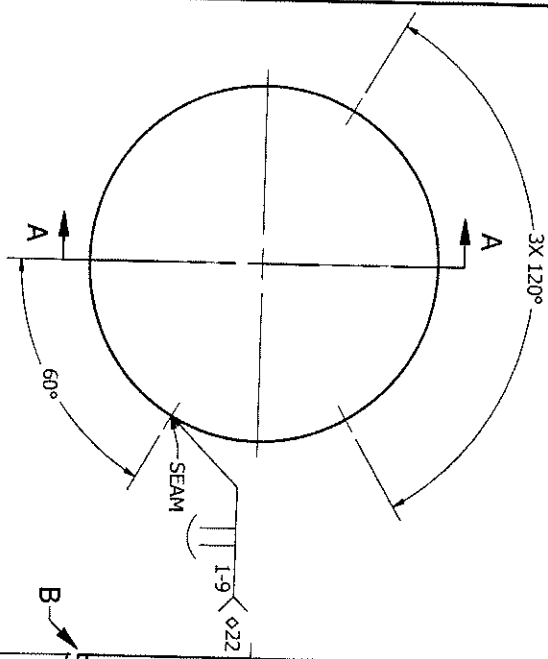
MATERIAL: PL 22 Ø X 65 1/4 X 1/32 THK
Aluminum-6061 ASTM B209
T4 TEMPER
FINISH: #8 MIRROR FINISH

Information Copy

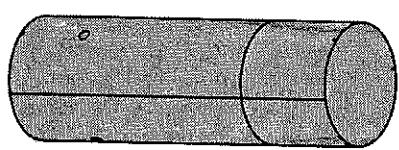
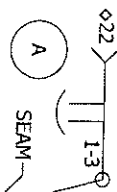
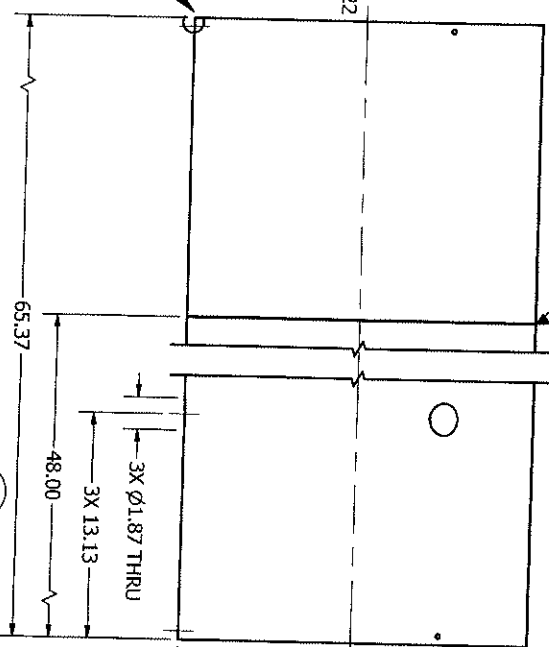


NOTES: (UNLESS OTHERWISE SPECIFIED)				TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.			
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.				X.X ± .030		DWG: MAB 11/12/2009 CHK: JHM 12/28/2009 APP: JHM 12/28/2009			
ALL DIMENSIONS APPLY AFTER FINISH.				X.XX ± .010					
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.				X.XXX ± .005					
3. SURFACE TEXTURE/FINISH 64 RMS				ANGULAR ± 1/2°					
 www.edencyrogenics.com				8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949					
SIZE	DRAWING/PART NUMBER			SHEET	REV	TITLE			
B	BC-02128-0033			1 OF 1	A	BC-02128 SIDE HEAT SHIELD			
						SCALE: 1:8			

6X .50
6X Ø.28 THRU
DETAIL B
SCALE 3 : 2



SECTION A-A
SCALE 1 : 7



SCALE 1 : 20

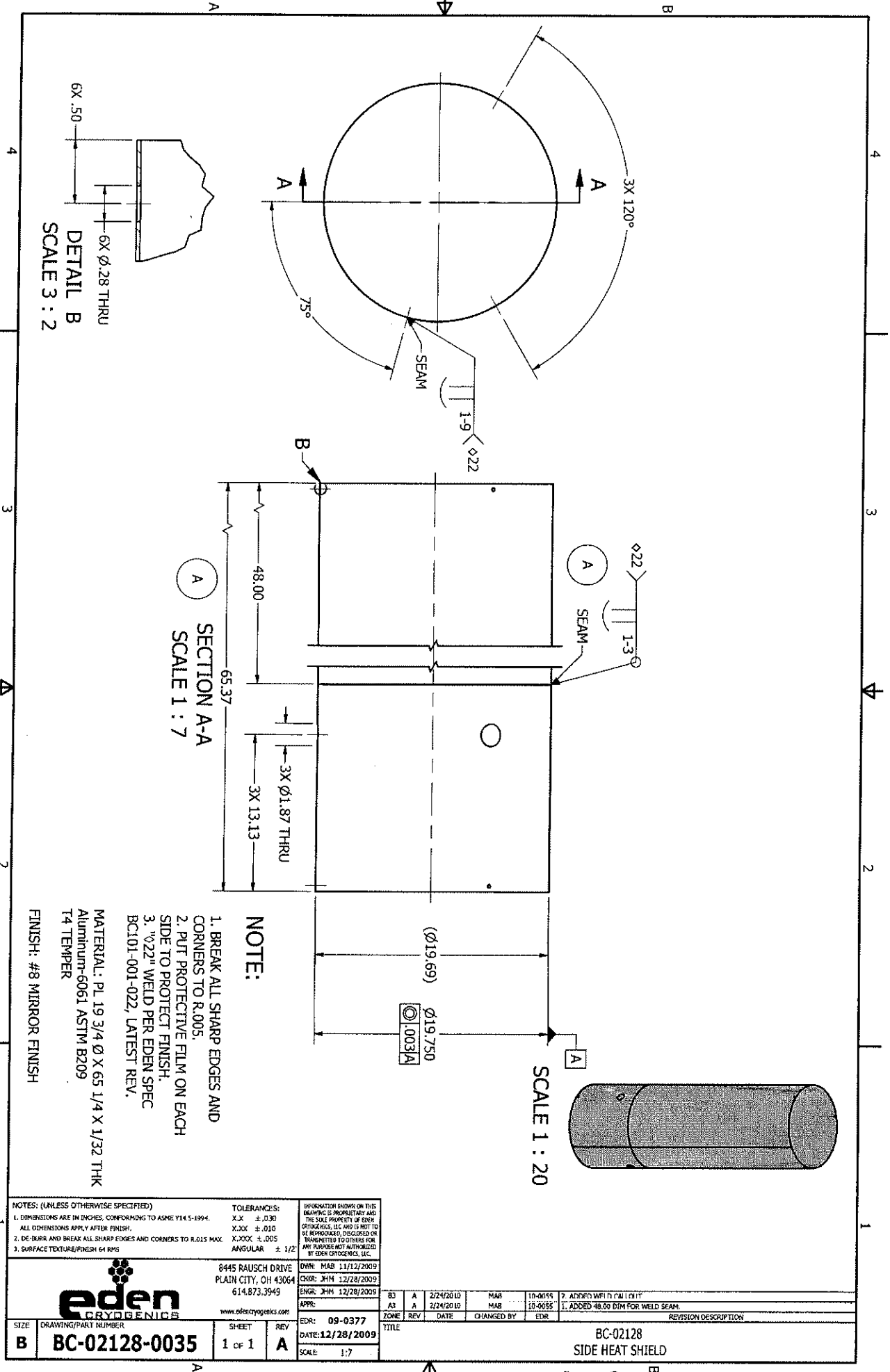
NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. PUT PROTECTIVE FILM ON EACH SIDE TO PROTECT FINISH.
3. "Ø.22" WELD PER EDEN SPEC BCI01-001-022, LATEST REV.

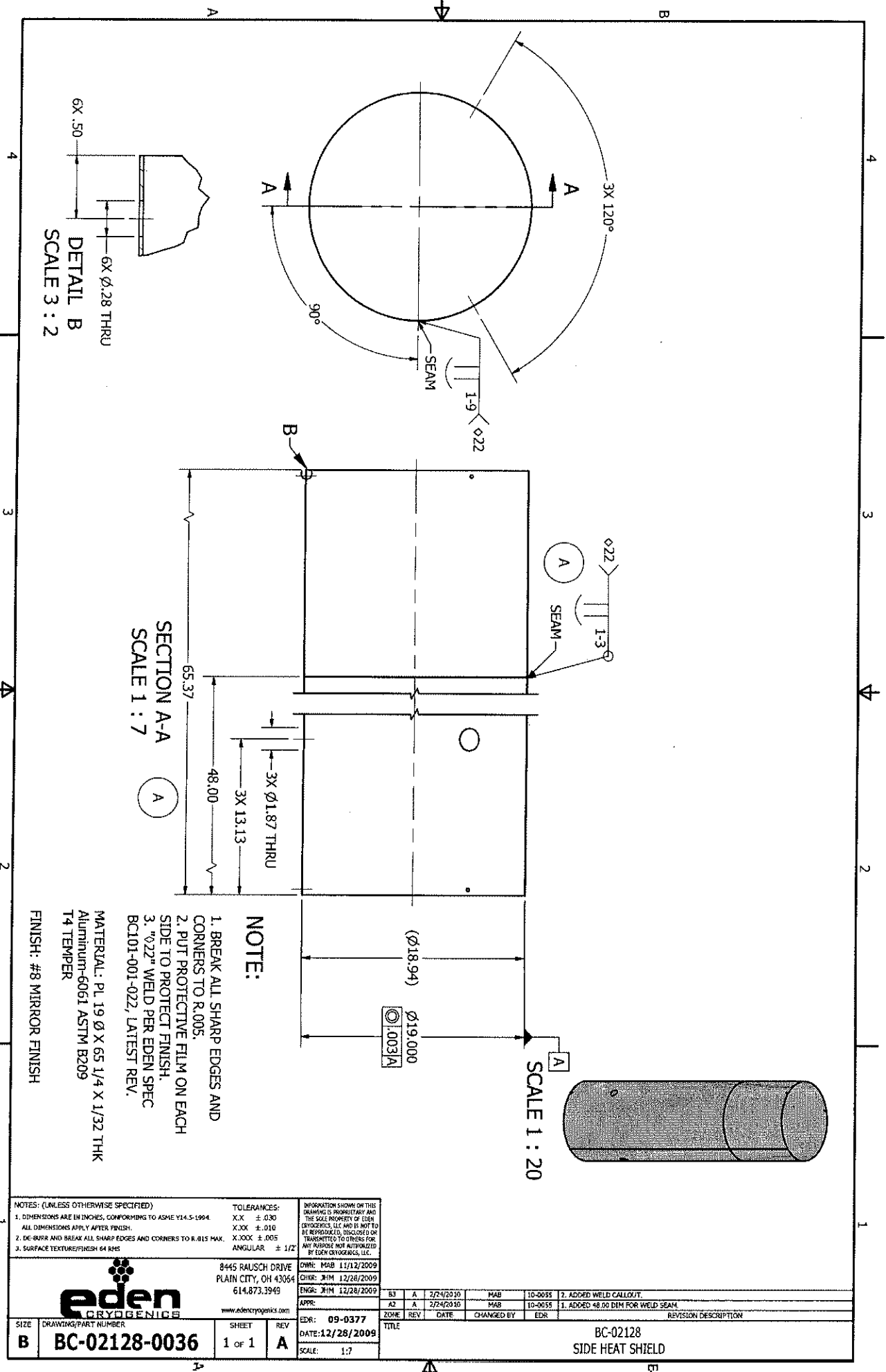
MATERIAL: PL 20 1/2 Ø X 65 1/4 X 1/32 THK
Aluminum-6061 ASTM B209
T4 TEMPER
FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 11/12/2009	
2. ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHKD: JHM 12/28/2009	
3. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		APPR: JHM 12/28/2009	
4. SURFACE TEXTURE/FINISH: 64 RMS		ANGULAR ± 1/2		EDR: 09-0377	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DATE: 12/28/2009		SCALE: 1:7	
EDEN CRYOGENICS		SHEET 1 OF 1		REV A	
SIZE B		DRAWING/PART NUMBER BC-02128-0034		TITLE BC-02128 SIDE HEAT SHIELD	

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
A3	A	2/24/2010	MAB	10-0055	2. ADDED WELD CALLOUT.
A2	A	2/24/2010	MAB	10-0055	1. ADDED 48.00 DIM FOR WELD SEAM.

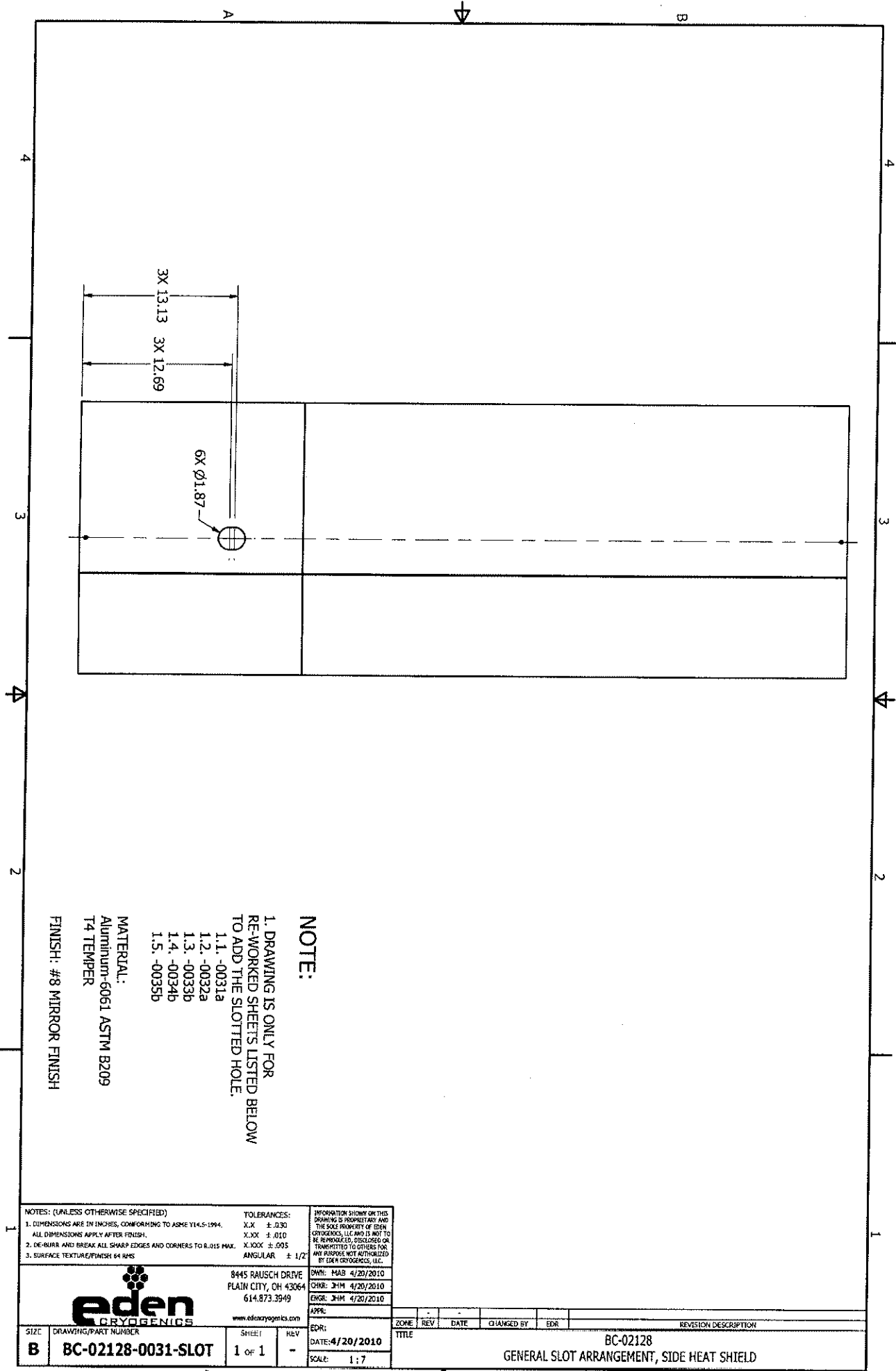


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NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		ENGR: MAB 11/12/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHGR: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		APPR:	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2"		DATE: 12/28/2009	
EDEN CRYOGENICS		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949		TITLE	
www.edencyro.com		SHEET 1 of 1		BC-02128	
DRAWING/PART NUMBER		REV A		SIDE HEAT SHIELD	
BC-02128-0036		DATE: 12/28/2009		SCALE: 1:7	

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
B3	A	2/24/2010	MAB	10-0055	2. ADDED WELD CALLOUT
A2	A	2/24/2010	MAB	10-0058	1. ADDED 48.00 DIM FOR WELD SEAM



NOTE:

1. DRAWING IS ONLY FOR
RE-WORKED SHEETS LISTED BELOW
TO ADD THE SLOTTED HOLE.

- 1.1. -0031a
- 1.2. -0032a
- 1.3. -0033b
- 1.4. -0034b
- 1.5. -0035b

MATERIAL:
Aluminum-6061 ASTM B209
T4 TEMPER
FINISH: #8 MIRROR FINISH

NOTES: (UNLESS OTHERWISE SPECIFIED)

- 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
- ALL DIMENSIONS APPLY AFTER FINISH.
- 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
- 3. SURFACE TEXTURE/FINISH 54 RMS

TOLERANCES:

- X.X ± .030
- X.XX ± .010
- X.XXX ± .005
- ANGULAR ± 1/2°

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TRANSMITTED TO OTHERS FOR
ANY PURPOSE NOT AUTHORIZED
BY EDEN CRYOGENICS, LLC.

OWN: MAB 4/20/2010

CHK: JHM 4/20/2010

ENG: JHM 4/20/2010

APP:

EDR:

DATE: 4/20/2010

SCALE: 1:1

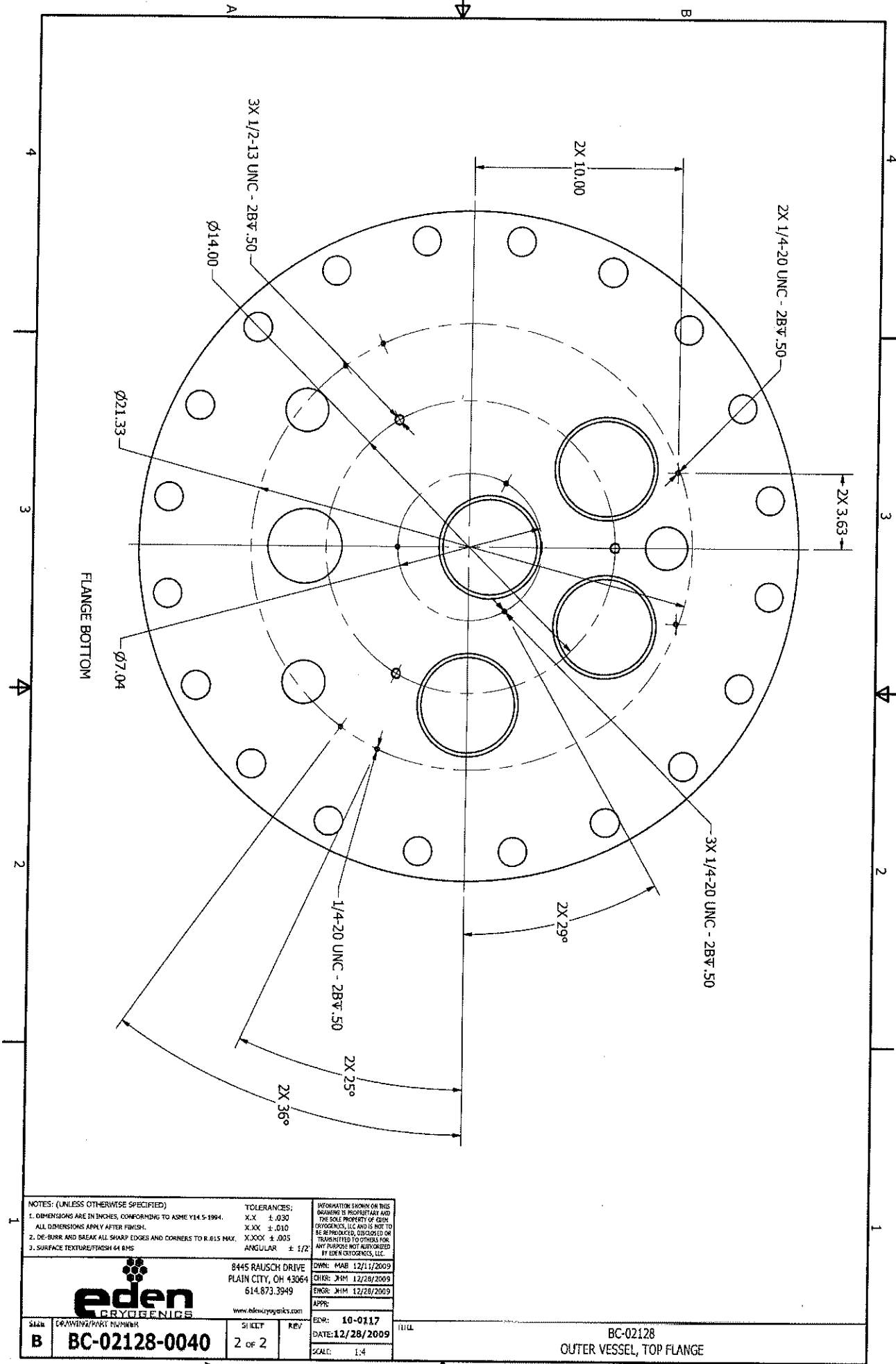


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SIZE	DRAWING/PART NUMBER	SHEET	REV	EDR	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
B	BC-02128-0031-SLOT	1 OF 1	-		4/20/2010			BC-02128 GENERAL SLOT ARRANGEMENT, SIDE HEAT SHIELD

Information Copy



NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.615 MAX.
3. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.



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614.873.3949

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DWG: MAB 12/11/2009
CHKR: JHM 12/28/2009
ENGR: JHM 12/28/2009
APPR:

SHEET
B
DRAWING/PART NUMBER
BC-02128-0040

SHEET
2 OF 2

REV

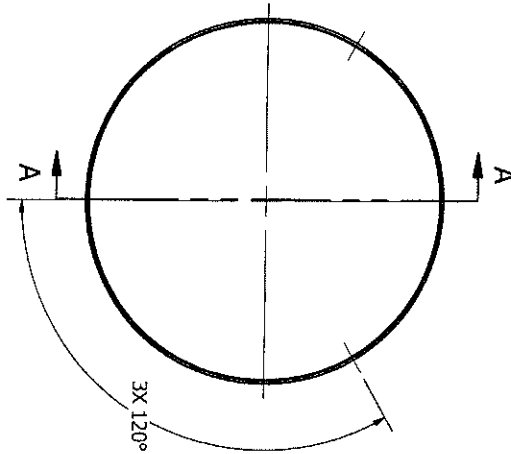
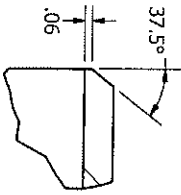
EDR: 10-0117
DATE: 12/28/2009
SCALE: 1:4

TITLE

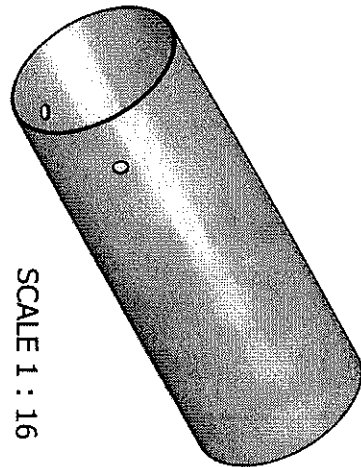
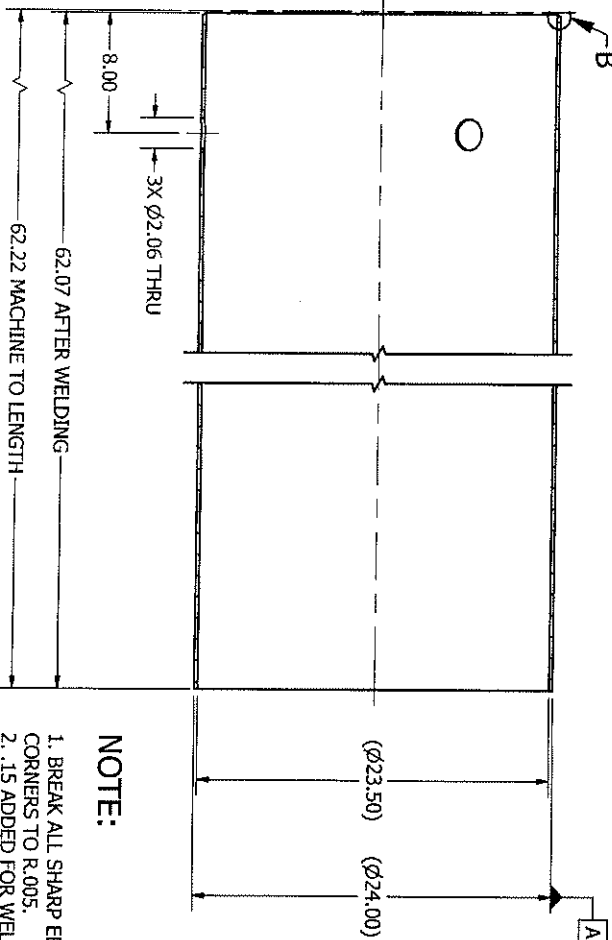
BC-02128
OUTER VESSEL, TOP FLANGE

Information Copy

DETAIL B
SCALE 1 : 1



SECTION A-A
SCALE 1 : 8



SCALE 1 : 16

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. .15 ADDED FOR WELD SHRINKAGE.

MATERIAL: PIPE, 24 NPS X SCH 10 X 62 1/4
Stainless Steel 304/304L ASME SA312
PI-384-010-021
FINISH: NATURAL

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. ALL DIMENSIONS APPLY AFTER FINISH.
3. DEBURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.005 MAX.
4. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS REPRESENTED AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.

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DRN: MAB 11/2/2009
CHK: JHM 12/23/2009
ENGR: JHM 12/29/2009

APPR: [Signature]

EDR: 09-0377

DATE: 12/28/2009

SCALE: 1:8

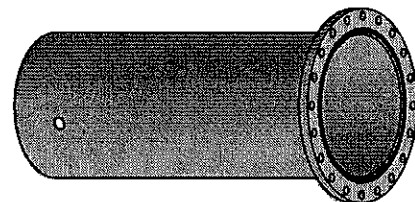
SIZE: B
DRAWING/PART NUMBER: BC-02128-0043

SHEET: 1 of 1
REV: -

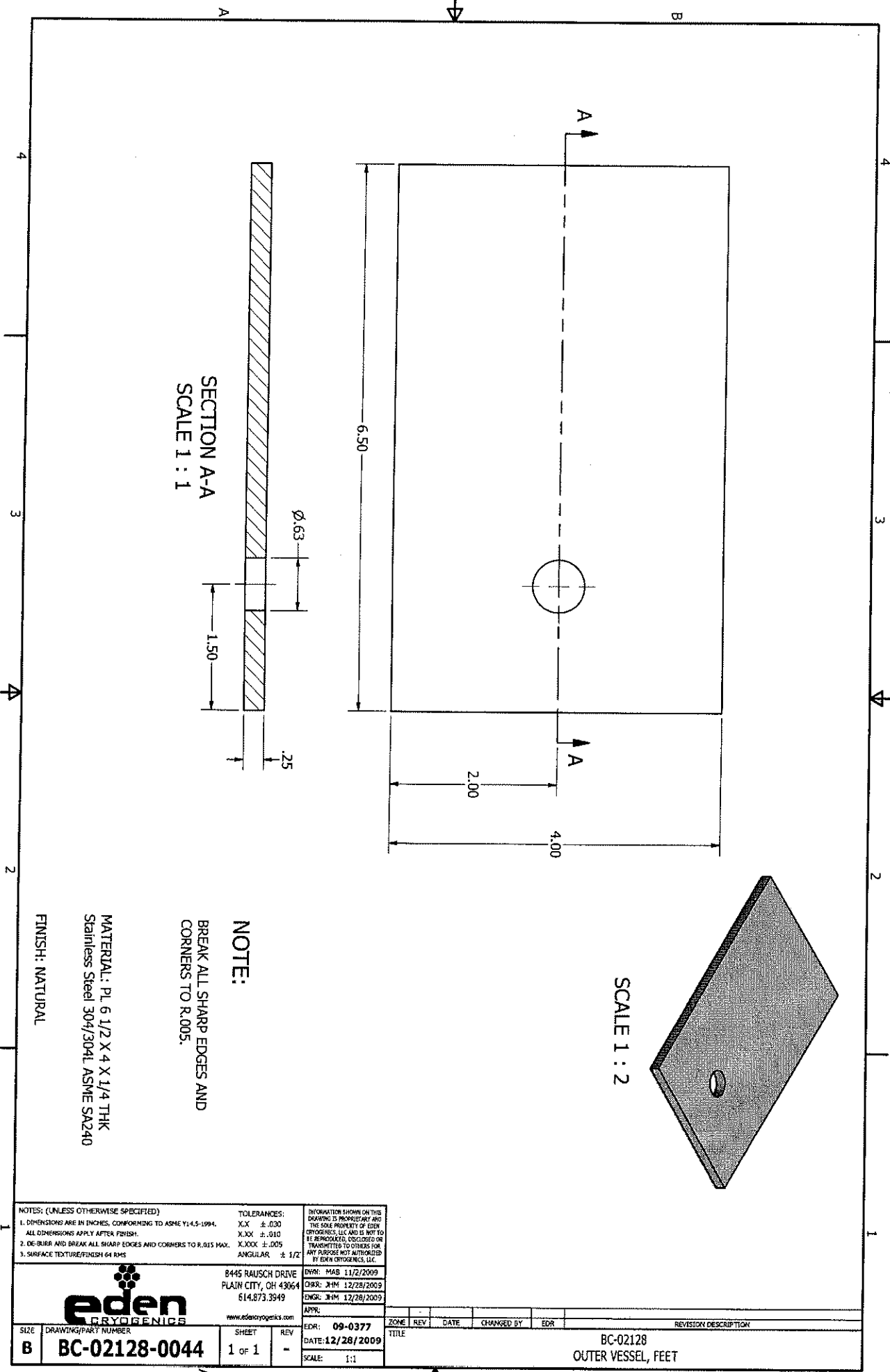
ZONE: [Blank]
REV: [Blank]
DATE: [Blank]
CHANGED BY: [Blank]
EDR: [Blank]

BC-02128
VACUUM VESSEL, PIPE, 24 NPS X SCH 10

Information Copy



v10.18.12 75 / 424

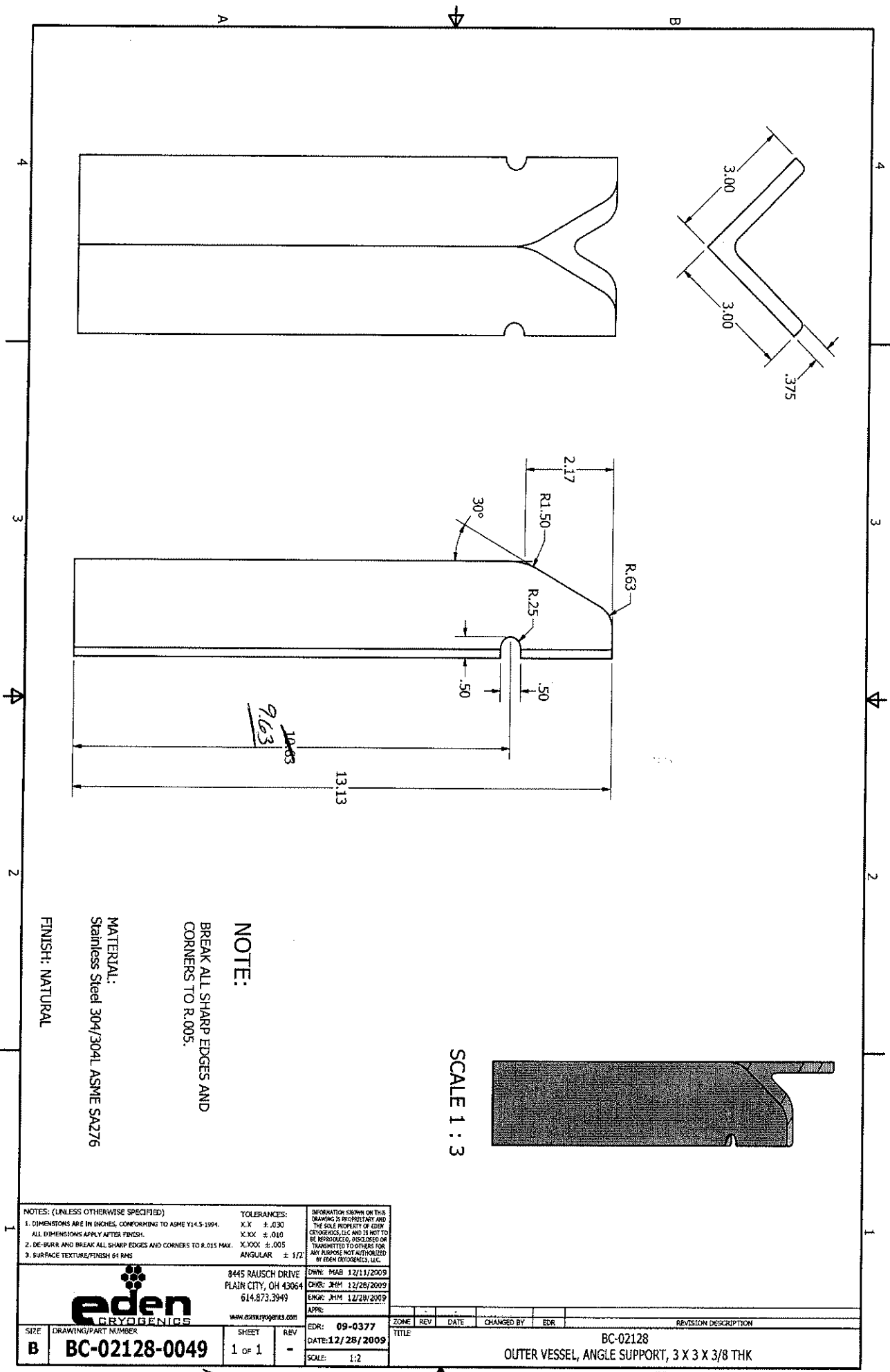


NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CYTOGENICS, LLC AND IS NOT TO BE REPRODUCED, UNLESS OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CYTOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWN: MAB 11/2/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.005 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APR:	
				EDR: 09-0377	
				DATE: 12/28/2009	
				SCALE: 1:1	



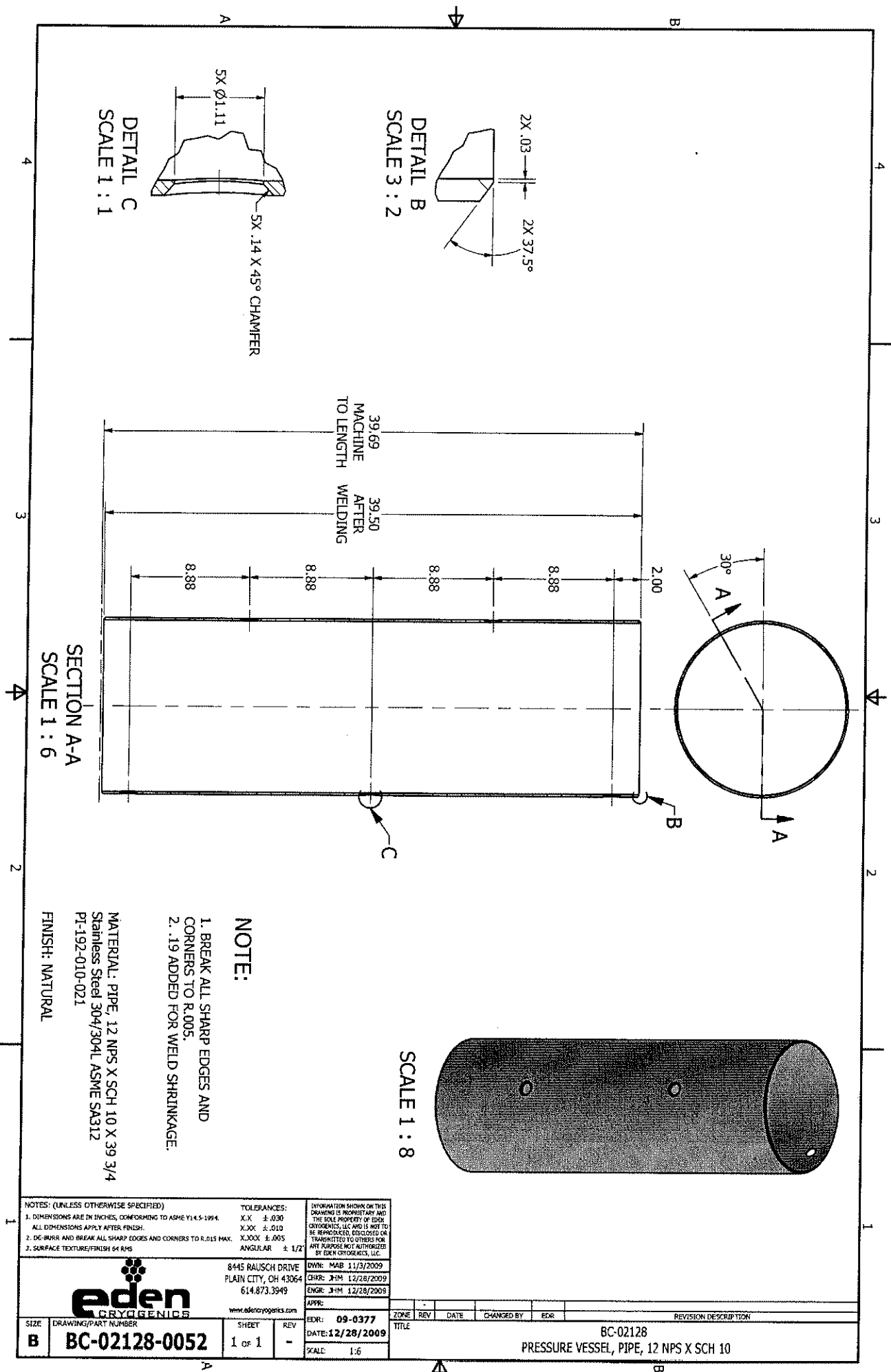
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.873.3949
www.edencytogenics.com

SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
B	BC-02128-0044	1 OF 1	-						
				BC-02128 OUTER VESSEL, FEET					



NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWN: MAB 12/11/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHKD: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.005 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2°		APPR:	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyro.com		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:2		ZONE REV DATE CHANGED BY EDR	
SIZE B		DRAWING/PART NUMBER BC-02128-0049		TITLE BC-02128 OUTER VESSEL, ANGLE SUPPORT, 3 X 3 X 3/8 THK	
SHEET 1 OF 1		REV -		REVISION DESCRIPTION	





NOTE:

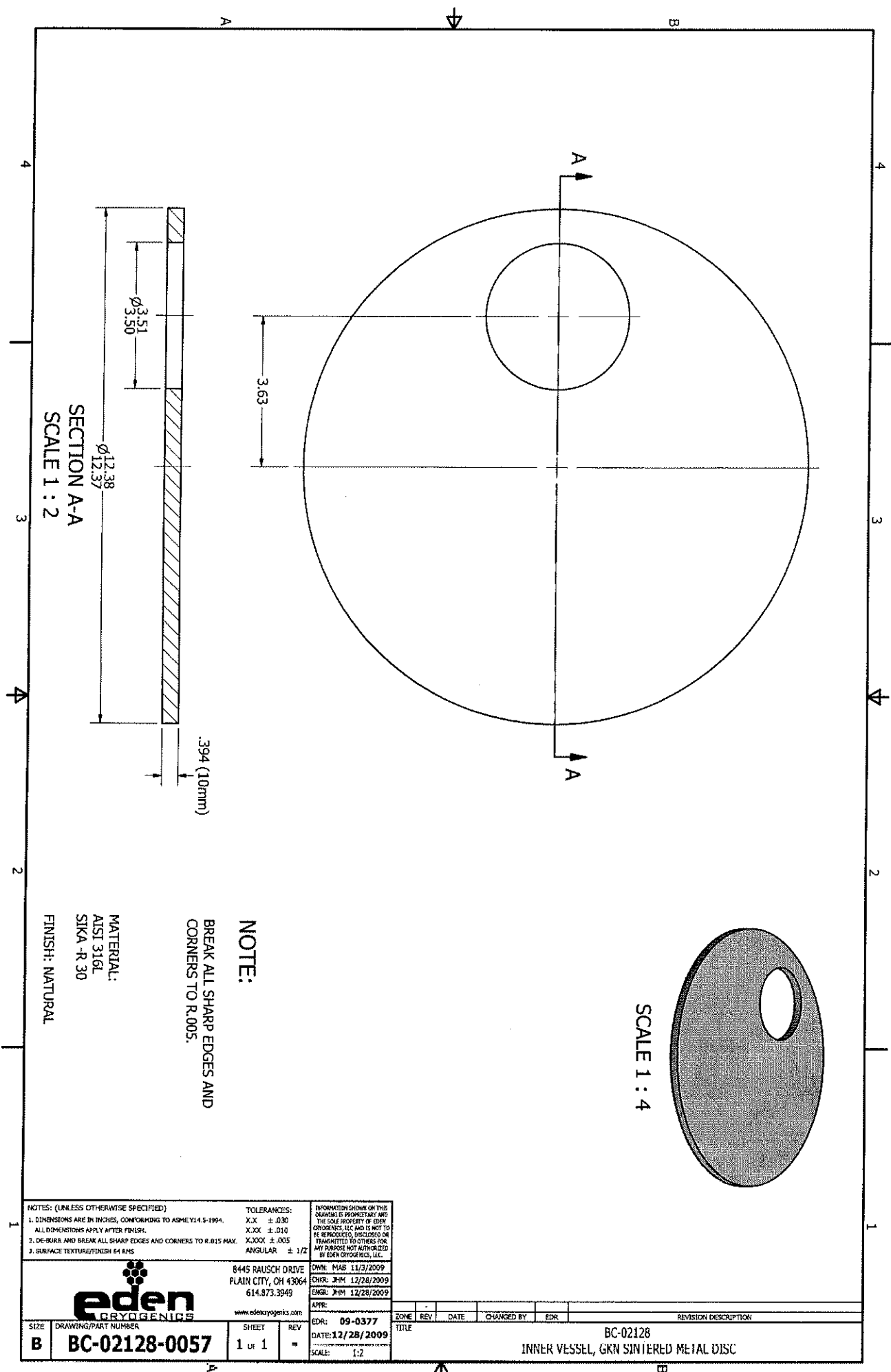
1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. .19 ADDED FOR WELD SHRINKAGE.

MATERIAL: PIPE, 12 NPS X SCH 10 X 39 3/4
Stainless Steel 304/304L ASME SA312
PT-192-010-021

FINISH: NATURAL

SCALE 1 : 8

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWG: MAB 11/3/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APP: _____	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		EDEN CRYOGENICS		ZONE REV DATE CHANGED BY EDR	
SIZE B		DRAWINGS/PART NUMBER		TITLE	
BC-02128-0052		SHEET 1 OF 1		BC-02128 PRESSURE VESSEL, PIPE, 12 NPS X SCH 10	
DATE: 12/28/2009		REV -		REVISION DESCRIPTION	
SCALE: 1:6					




SECTION A-A
SCALE 1 : 2

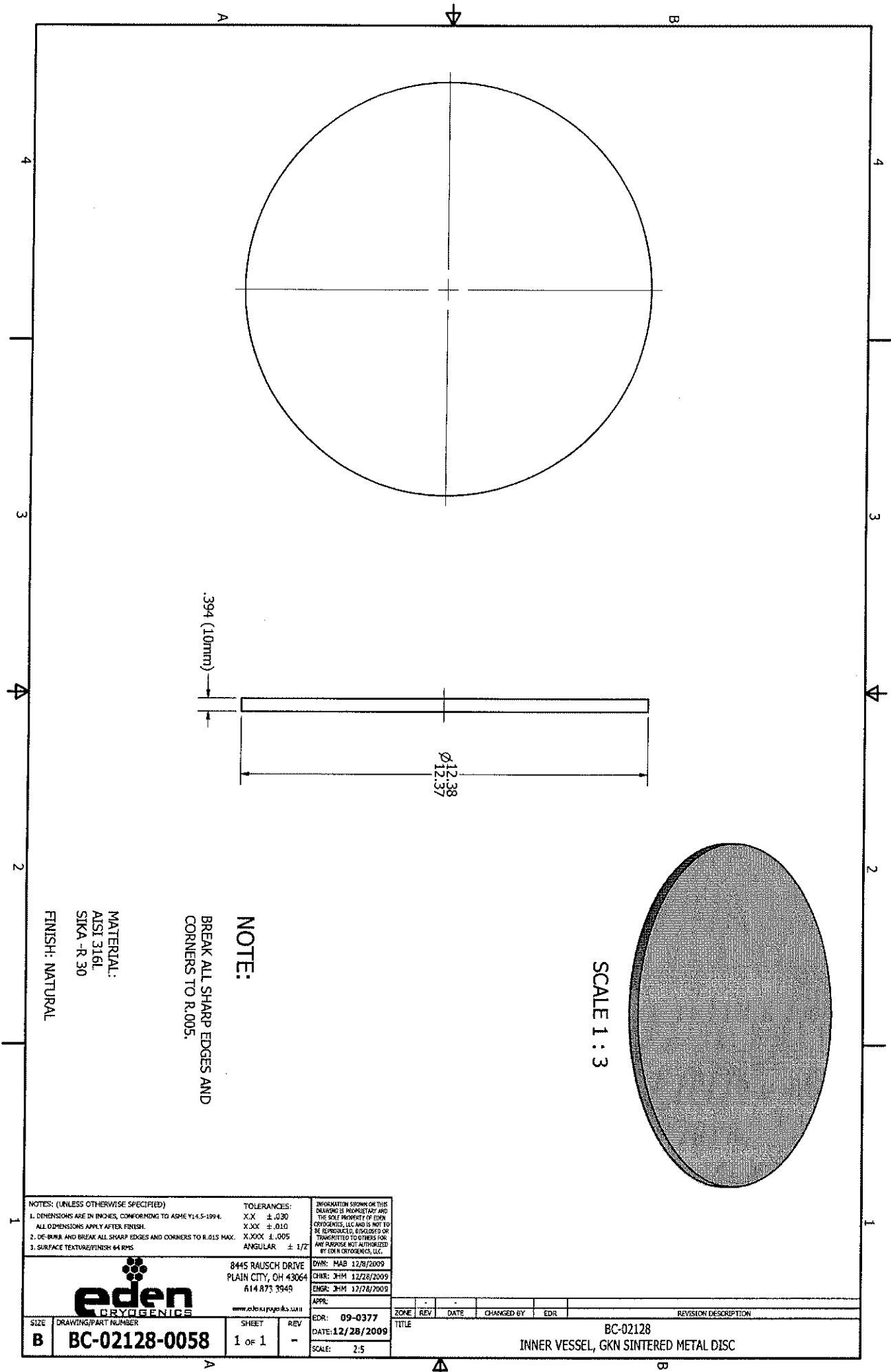
SCALE 1 : 4

NOTE:

BREAK ALL SHARP EDGES AND
CORNERS TO R.005.

MATERIAL:
ASTI 316L
SIKA -R-30
FINISH: NATURAL


NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		OWN: MAB 11/3/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHGR: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPR:	
		8445 RAUSCH DRIVE		EDR: 09-0377	
		PLAIN CITY, OH 43064		DATE: 12/28/2009	
		614.873.3949		SCALE: 1:2	
www.edencyogenics.com		SHEET		ZONE REV DATE CHANGED BY EDR	
1 of 1		REV		REVISION DESCRIPTION	
B		BC-02128-0057		BC-02128	
				INNER VESSEL, GRN SINTERED METAL DISC	

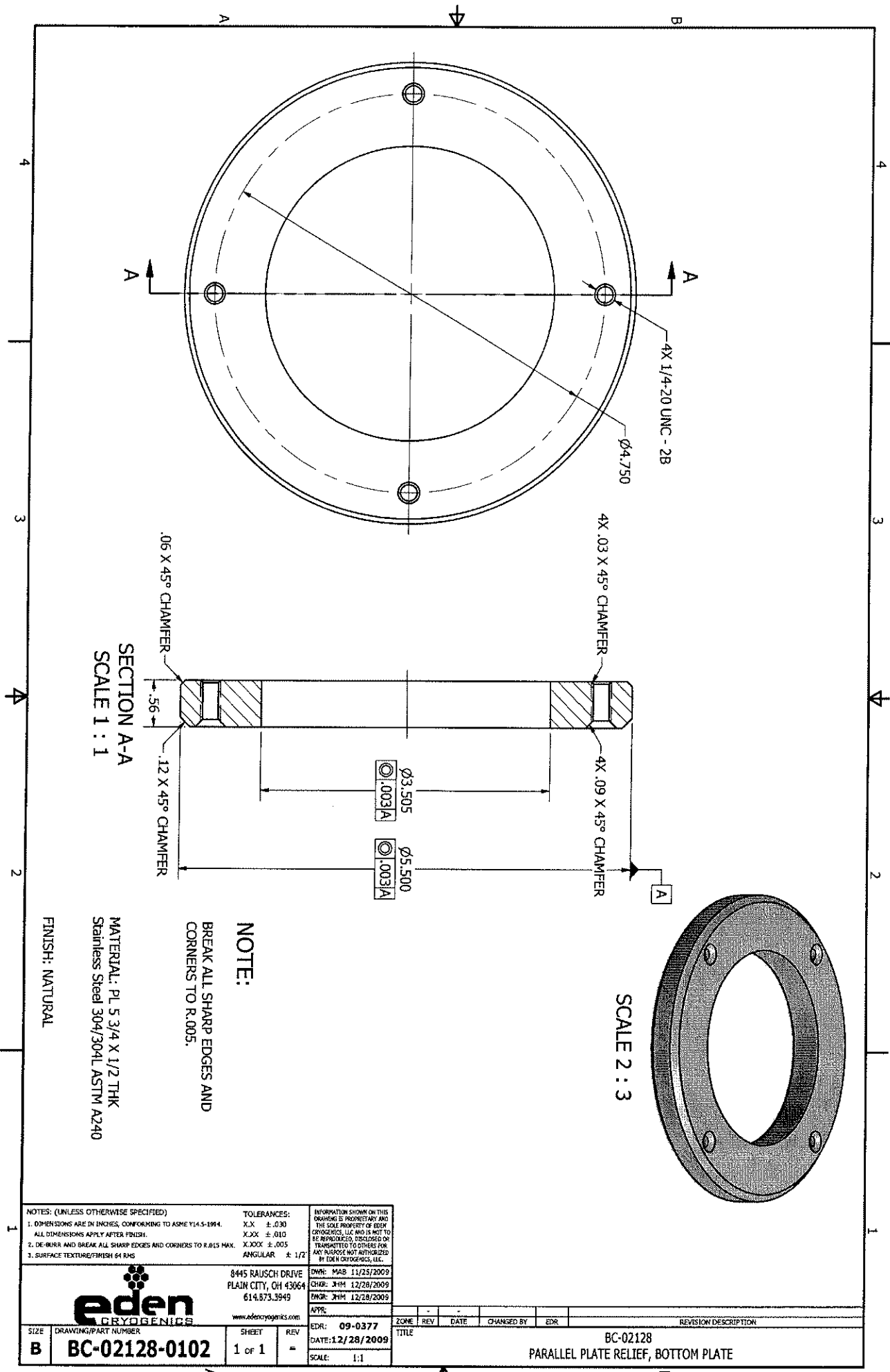


MATERIAL:
ALSI 316L
SIKA-R 30
FINISH: NATURAL

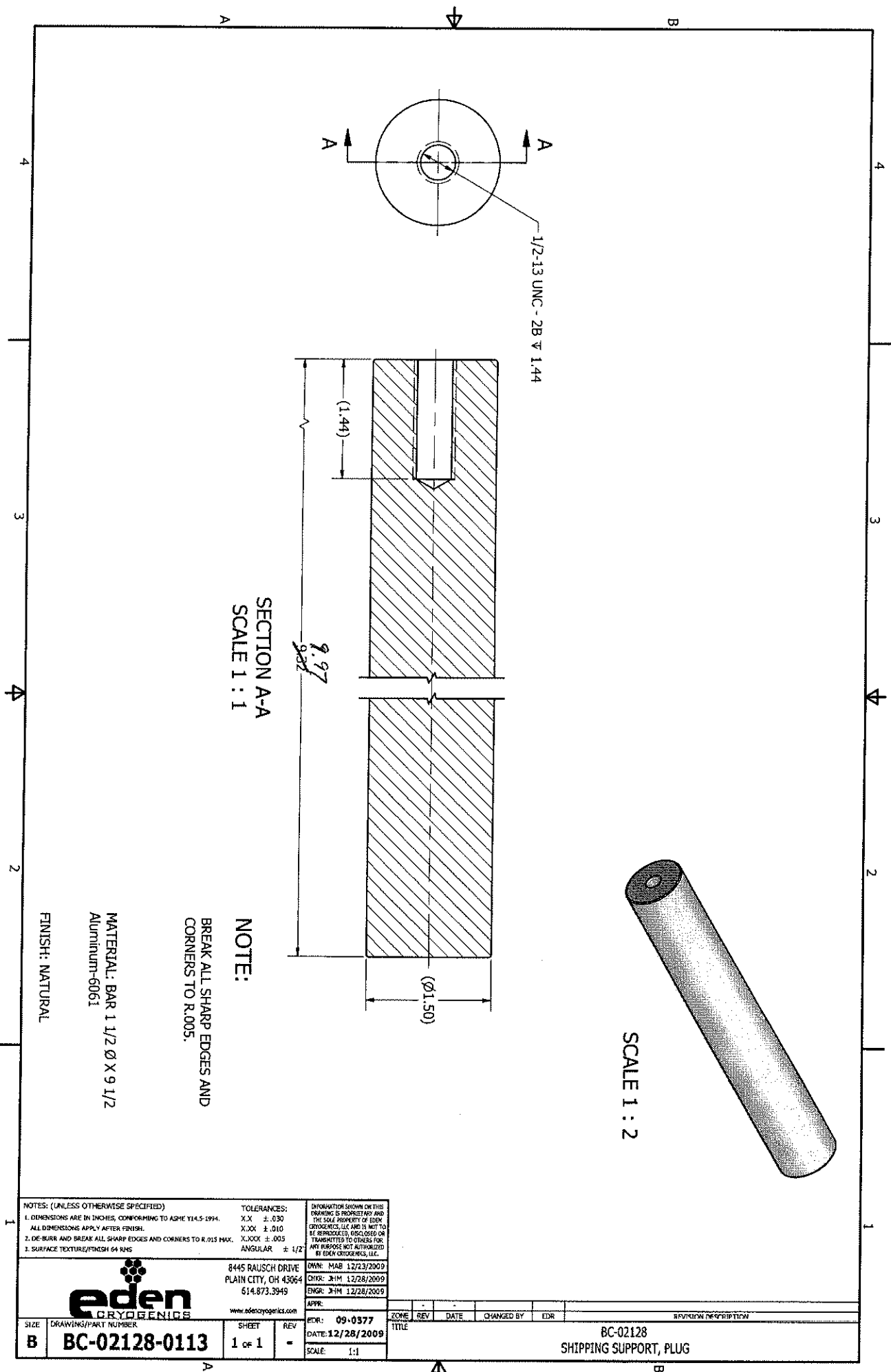
NOTE:
BREAK ALL SHARP EDGES AND
CORNERS TO R.005.

SCALE 1 : 3

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS FOR INFORMATION ONLY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 12/8/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHN: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH: 64 RMS		ANGULAR ± 1/2		APPR:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3348 www.edencyro.com		EDR: 09-0377 DATE: 12/28/2009 SCALE: 2:5	
SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE REV DATE CHANGED BY EDR REVISION DESCRIPTION	
B	BC-02128-0058	1 OF 1	-	BC-02128 INNER VESSEL, GKN SINTERED METAL DISC	



NOTES: (UNLESS OTHERWISE SPECIFIED)			TOLERANCES:			INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, COPIED, OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.		
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.			X.X ± .030			DWG: MAB 11/25/2009		
2. ALL DIMENSIONS APPLY AFTER FINISH.			X.XX ± .010			CHK: JHM 12/28/2009		
3. DEBURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.			X.XXX ± .005			PRG: JHM 12/28/2009		
4. SURFACE TEXTURE/FINISH 64 RMS			ANGULAR ± 1/2			APP:		
8445 RAUSCH DRIVE			www.edencyogenics.com			EDR: 09-0377		
PLAIN CITY, OH 43064			DATE: 12/28/2009			DATE: 12/28/2009		
614.873.3949			SHEET			SCALE: 1:1		
1 of 1			REV			ZONE		
B			=			REV		
BC-02128-0102			TITLE			DATE		
			PARALLEL PLATE RELIEF, BOTTOM PLATE			CHANGED BY		
						EDR		
						REVISION DESCRIPTION		




SECTION A-A
SCALE 1 : 1

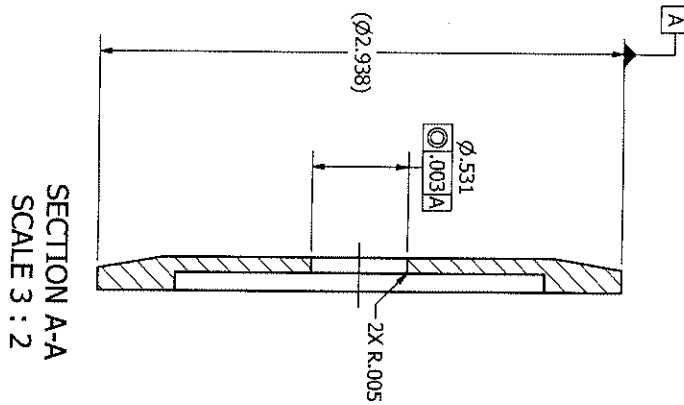
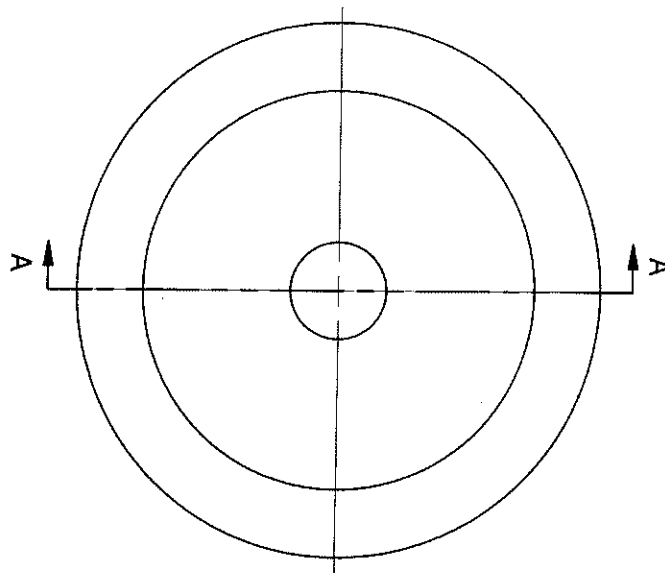
SCALE 1 : 2

NOTE:
BREAK ALL SHARP EDGES AND
CORNERS TO R.005.

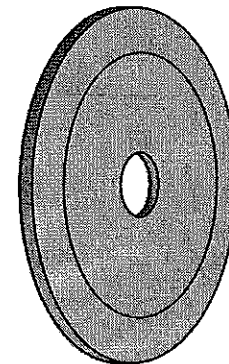
MATERIAL: BAR 1 1/2 Ø X 9 1/2
Aluminum-6061

FINISH: NATURAL

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 12/23/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHECKED: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGINEER: JHM 12/28/2009	
3. SURFACE TEXTURE/RAUGH 64 RMS		ANGULAR ± 1/2		APPROVED:	
		8445 RAUSCH DRIVE		ZONE	
		PLAIN CITY, OH 43064		REV	
www.edencyrogenics.com		614.873.3949		DATE	
SIZE	DRAWING/PART NUMBER	SHEET	REV	CHANGED BY	EDR
B	BC-02128-0113	1 of 1	-		
DATE: 09-0377		DATE: 12/28/2009		DIVISION DESCRIPTION	
SCALE: 1:1				BC-02128	
				SHIPPING SUPPORT, PLUG	



SECTION A-A
SCALE 3 : 2




SCALE 1 : 1

NOTE:

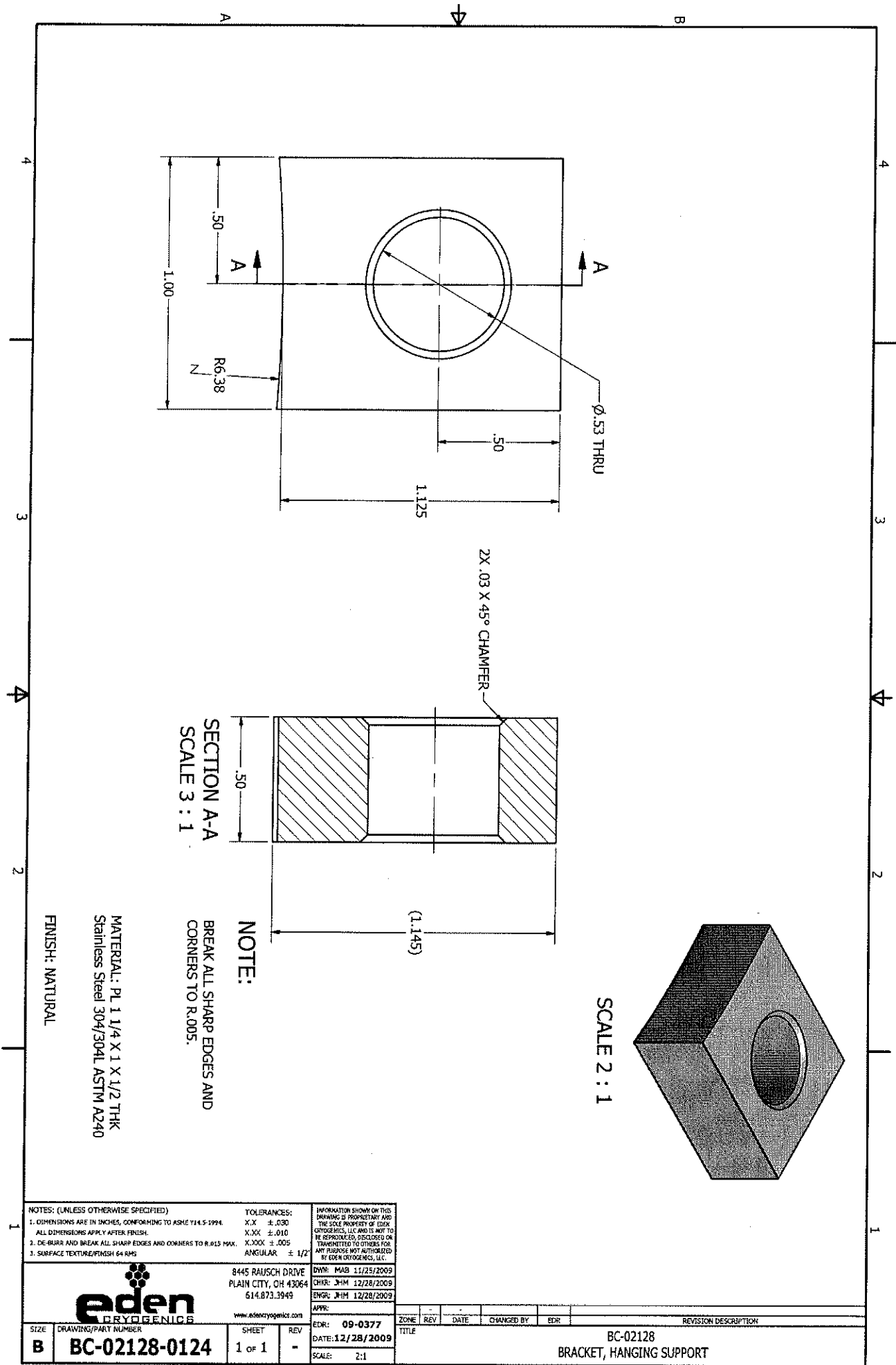
1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. MACHINE FROM 712003.

MATERIAL:
Stainless Steel 304/304L

FINISH: NATURAL

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		DEFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWN: MAB 12/23/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPL:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.673.3949		EDR: 09-0377 DATE: 12/28/2009 SCALE: 3:2	
www.edencygenics.com					

SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
B	BC-02128-0114	1 of 1	-						BC-02128 FLANGE, BLANK, NW50, MODIFIED, MDC VACUUM PRODUCTS



NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWN: MAB 11/25/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2°		APPR:	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyogenics.com		EDR: 09-0377		ZONE REV DATE CHANGED BY EDR	
DATE: 12/28/2009		SCALE: 2:1		REVISION DESCRIPTION	
SIZE B		DRAWING/PART NUMBER BC-02128-0124		BC-02128 BRACKET, HANGING SUPPORT	
SHEET 1 OF 1		REV -			

Information Copy

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CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4660

CERTIFIED BY EDEN CRYOGENICS, LLC
MAWP 165 PSI AT 932 °F
MAEWP 15 PSI AT 932 °F
MDMT -320 °F AT 165 PSI
EDEN SERIAL NO. 02128-01
YEAR BUILT 2010

BC-02128-1701

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4660

CERTIFIED BY EDEN CRYOGENICS, LLC
MAWP 165 PSI AT 932 °F
MAEWP 15 PSI AT 932 °F
MDMT -320 °F AT 165 PSI
EDEN SERIAL NO. 02128-02
YEAR BUILT 2010

BC-02128-1702

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4660

CERTIFIED BY EDEN CRYOGENICS, LLC
MAWP 165 PSI AT 932 °F
MAEWP 15 PSI AT 932 °F
MDMT -320 °F AT 165 PSI
EDEN SERIAL NO. 02128-03
YEAR BUILT 2010

BC-02128-1703

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4660

CERTIFIED BY EDEN CRYOGENICS, LLC
MAWP 165 PSI AT 932 °F
MAEWP 15 PSI AT 932 °F
MDMT -320 °F AT 165 PSI
EDEN SERIAL NO. 02128-01
YEAR BUILT 2010

BC-02128-1704

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4660

CERTIFIED BY EDEN CRYOGENICS, LLC
MAWP 165 PSI AT 932 °F
MAEWP 15 PSI AT 932 °F
MDMT -320 °F AT 165 PSI
EDEN SERIAL NO. 02128-02
YEAR BUILT 2010

BC-02128-1705

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4660

CERTIFIED BY EDEN CRYOGENICS, LLC
MAWP 165 PSI AT 932 °F
MAEWP 15 PSI AT 932 °F
MDMT -320 °F AT 165 PSI
EDEN SERIAL NO. 02128-03
YEAR BUILT 2010

BC-02128-1706

NOTE:

1. BLACK TEXT AND GRAPHICS.
2. 3/16 LETTER STAMP SIZE.

MATERIAL:
Stainless Steel 304/304L
LB-003-000-001

FINISH: NATURAL

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. ALL DIMENSIONS APPLY AFTER FINISH.
3. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
4. SURFACE TEXTURE/RTS 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS
DRAWING IS PROPRIETARY AND
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CRYOGENICS, LLC AND IS NOT TO
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TRANSMITTED TO OTHERS FOR
ANY PURPOSE NOT AUTHORIZED
BY EDEN CRYOGENICS, LLC.

DWN: MAB 3/10/2010
CHW: JHM 3/23/2010
ENGR: JHM 3/23/2010

APPR:

EDR: 10-0080

DATE: 3/23/2010

SCALE: 3:4

ZONE REV DATE CHANGED BY EDR

ADDED LABELS -1704, -1705 & -1706. DUPLICATES OF -1701, -1702 & -1703.

REVISION DESCRIPTION

eden
CRYOGENICS
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.873.3949
www.edencyogenics.com

DRAWING/PART NUMBER
BC-02128-1701

SIZE **B**

SHEET
1 OF 1

REV
A

Information Copy

4 3 2 1

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CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4860

CERTIFIED BY EDEN CRYOGENICS, LLC

MAWP 15 PSI AT 70 °F
MAEMP 0 PSI AT 70 °F
MDMT 70 °F AT 15 PSI
EDEN SERIAL NO. 02128-07
YEAR BUILT 2010

BC-02128-1707

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4860

CERTIFIED BY EDEN CRYOGENICS, LLC

MAWP 15 PSI AT 70 °F
MAEMP 0 PSI AT 70 °F
MDMT 70 °F AT 15 PSI
EDEN SERIAL NO. 02128-08
YEAR BUILT 2010

BC-02128-1708

eden
CRYOGENICS
8445 RAUSCH DRIVE PLAIN CITY, OHIO 43064
TOLL FREE 877-273-4860


CERTIFIED BY EDEN CRYOGENICS, LLC

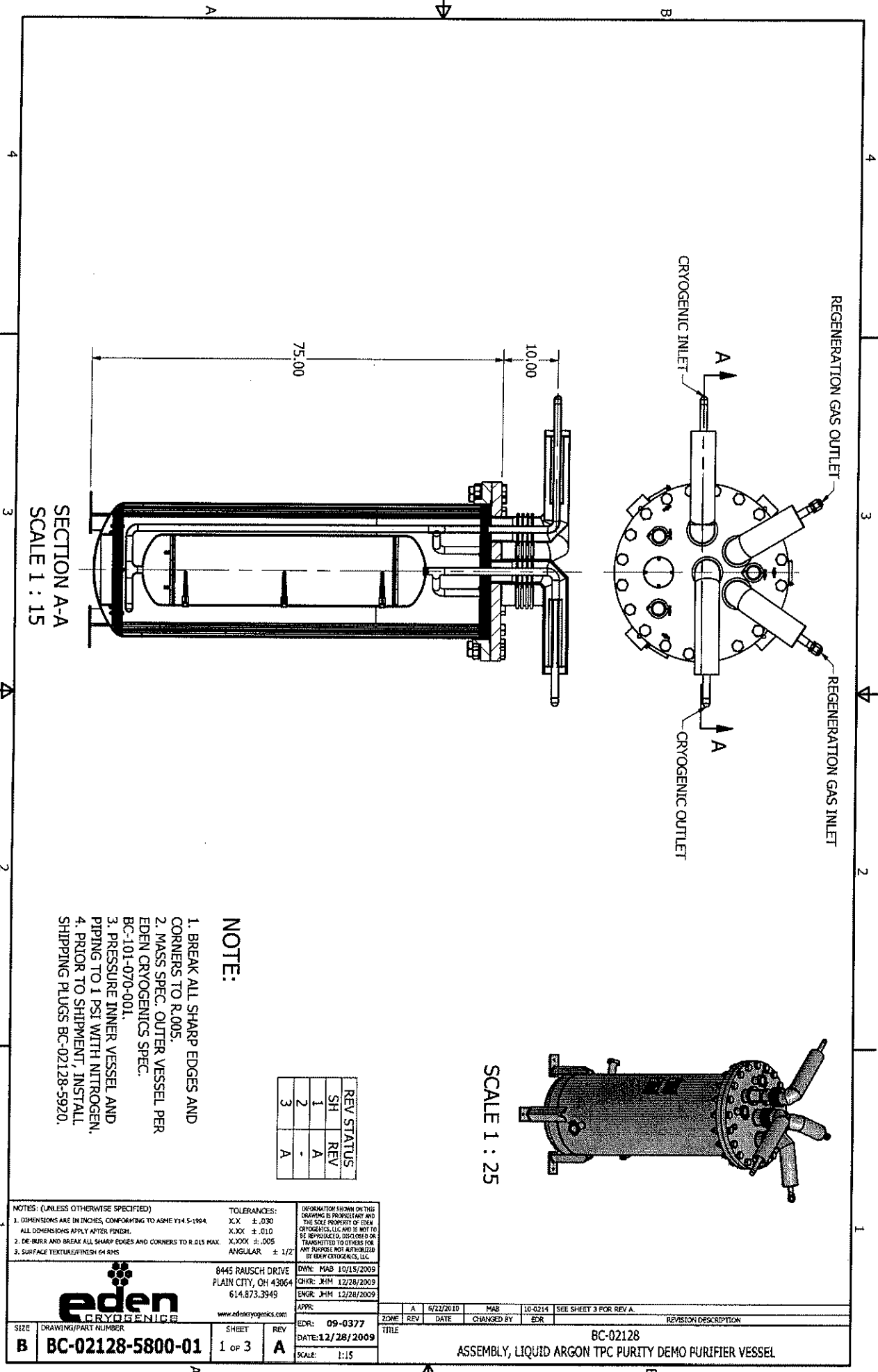
MAWP 15 PSI AT 70 °F
MAEMP 0 PSI AT 70 °F
MDMT 70 °F AT 15 PSI
EDEN SERIAL NO. 02128-09
YEAR BUILT 2010

BC-02128-1709

NOTE:
1. BLACK TEXT AND GRAPHICS.
2. 3/16 LETTER STAMP SIZE.

MATERIAL:
Stainless Steel 304/304L
LB-003-000-001
FINISH: NATURAL

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/DESIGN 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DWG: MAB 4/12/2010 CHKD: JHM 6/14/2010 ENGR: JHM 6/14/2010 APP: _____		EDR: 10-0205 DATE: 6/14/2010 SCALE: 3:4	
SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE REV DATE CHANGED BY EDR	
B	BC-02128-1707	1 OF 1	-	BC-02128 LABEL, CODED VESSEL	



SECTION A-A
SCALE 1 : 15

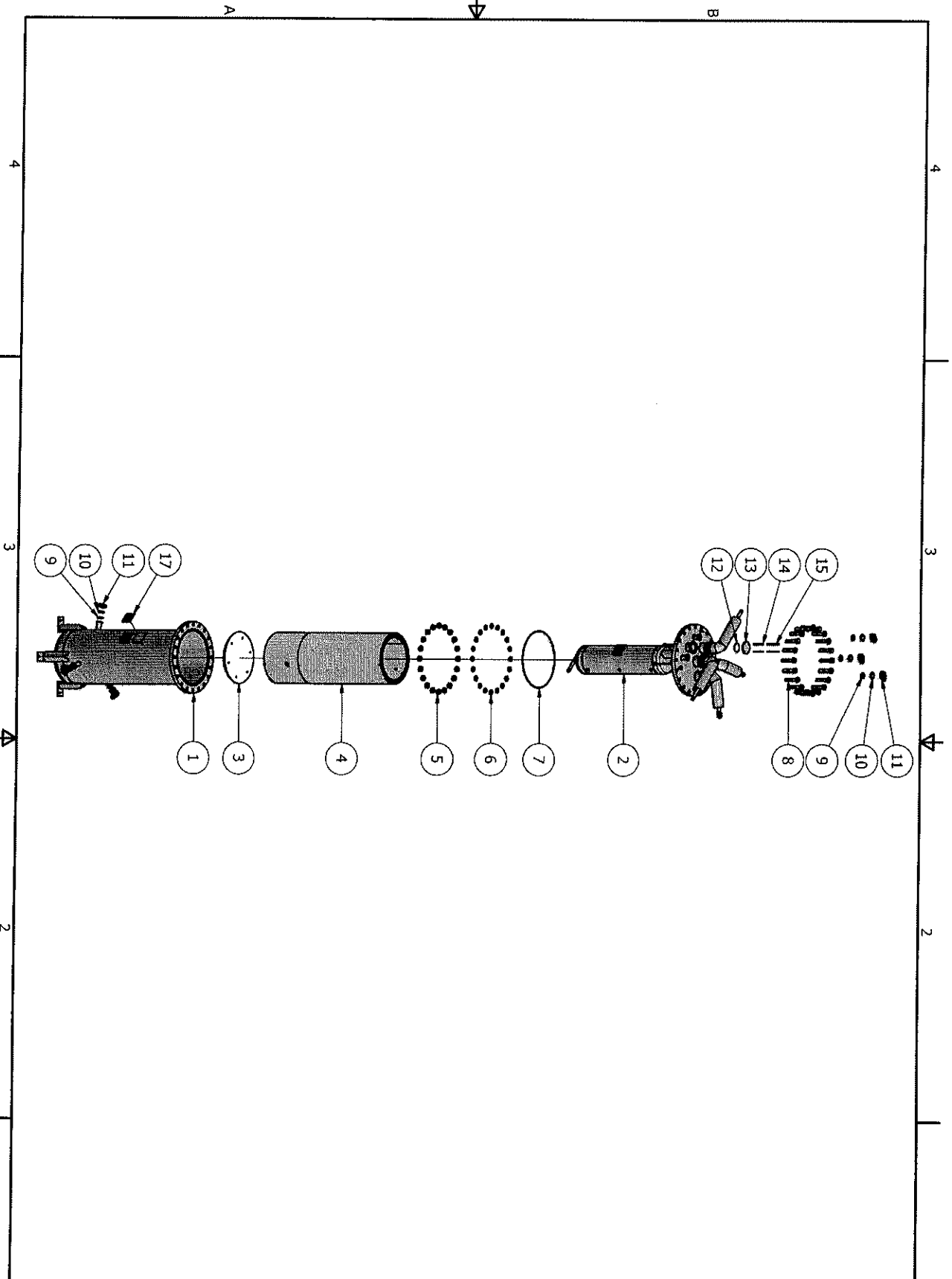
SCALE 1 : 25

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. MASS SPEC. OUTER VESSEL PER EDEN CRYOGENICS SPEC. BC-101-070-001.
3. PRESSURE INNER VESSEL AND PIPING TO 1 PSI WITH NITROGEN.
4. PRIOR TO SHIPMENT, INSTALL SHIPPING PLUGS BC-02128-5920.

REV STATUS	
SH	REV
1	A
2	-
3	A

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE: FRESH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC. DWG: MAB 10/15/2009 CHKD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR: _____ EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:15											
 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		<table border="1"> <tr> <th>ZONE</th> <th>REV</th> <th>DATE</th> <th>CHANGED BY</th> <th>DESCRIPTION</th> </tr> <tr> <td>A</td> <td>1</td> <td>6/22/2010</td> <td>MAB</td> <td>10-0214 SEE SHEET 3 FOR REV A.</td> </tr> </table>				ZONE	REV	DATE	CHANGED BY	DESCRIPTION	A	1	6/22/2010	MAB	10-0214 SEE SHEET 3 FOR REV A.
ZONE	REV	DATE	CHANGED BY	DESCRIPTION											
A	1	6/22/2010	MAB	10-0214 SEE SHEET 3 FOR REV A.											
SIZE: B DRAWING/PART NUMBER: BC-02128-5800-01		SHEET: 1 OF 3		REV: A											
TITLE: BC-02128 ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL															



NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.													
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrognics.com		OWN: MAB 10/15/2009 CHG: JHM 12/28/2009 ENGR: JHM 12/28/2009		APPR:													
SIZE: B DRAWING/PART NUMBER: BC-02128-5800-01 SHEET: 2 OF 3 REV: -	CTR: 09-0377 DATE: 12/28/2009 SCALE: 1:40		<table border="1"> <thead> <tr> <th>ZONE</th> <th>REV</th> <th>DATE</th> <th>CHANGED BY</th> <th>EDR</th> <th>REVISION DESCRIPTION</th> </tr> </thead> <tbody> <tr> <td colspan="6"> TITLE: BC-02128 ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL </td> </tr> </tbody> </table>			ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION	TITLE: BC-02128 ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL					
ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION												
TITLE: BC-02128 ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL																	

Information Copy

PARTS LIST					
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	1	BC-02128-5810	WELDMENT, VACUUM VESSEL		Welded Stainless Steel 304/304L
2	1	BC-02128-5815	FINAL ASSEMBLY, LAR PRESSURE VESSEL W/ PORTS		Welded Stainless Steel 304/304L
3	1	BC-02128-5890	ASSEMBLY, HEAT SHIELDS, BOTTOM		
4	1	BC-02128-5900	ASSEMBLY, HEAT SHIELDS, SIDE		
5	20	FA-020-812-006	HEX NUT, INCH, 1 1/4-7 UNC		Stainless Steel 304/304L ASTM A194 GR 8
6	20	FA-020-812-030	SPRING LOCK WASHER, 1 1/4		Stainless Steel 18-8
7	1	HW-001-001-474	VITON O-RING	2-474	Viton
8	20	FA-020-112-326	HEX BOLT, INCH, 1 1/4-7 UNC X 6 LG		Stainless Steel 304/304L ASTM A193 GR B8
9	6	710003	CENTERING RING, MDC VACUUM PRODUCTS		
10	6	712003	FLANGE, BLANK, MW50, MDC VACUUM PRODUCTS		Stainless Steel 304/304L
11	6	701003	CLAMP, HINGED, MDC VACUUM PRODUCTS		
12	1	HW-001-001-241	VITON O-RING	2-241	Viton
13	1	BC-02128-0103	PARALLEL PLATE RELIEF, TOP PLATE		Stainless Steel 304/304L ASTM A240
14	4	BC-02128-0104	LIFT PLATE, SPRING	9663K56	Stainless Steel 302
15	4	BC-02128-0105	SHOULDER SCREW, 5/16 Ø X 3 1/2, 1/4-20 UNC	90298A597	Stainless Steel 18-8
16	3	BC-02128-5920	SHIPPING PLUG		
17	1	BC-02128-1704	LABEL, CODED VESSEL, DUPLICATE	LB-003-000-001	Stainless Steel 304/304L

VESSEL TAGS			
SERIAL NO.	PRESSURE VESSEL LABEL	DUPLICATE LABEL	VACUUM VESSEL LABEL
02128-01	BC-02128-1701	BC-02128-1704	BC-02128-1707

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
ALL DIMENSIONS APPLY AFTER FINISH.

2. DE BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.

3. SURFACE TEXTURE/FRESH 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2

DEFORMATION SHOWN ON THIS DRAWING IS THE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.

DRAWN: MAB 10/15/2009
CHECKED: JHM 12/28/2009
APP: _____
CDR: 02-0377
DATE: 12/28/2009
SCALE: _____

8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
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eden CRYOGENICS

SHEET 3 OF 3
REV A

SIZE B
DRAWING/PART NUMBER BC-02128-5800-01

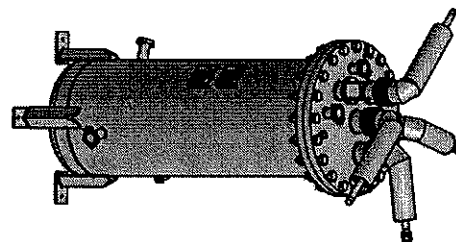
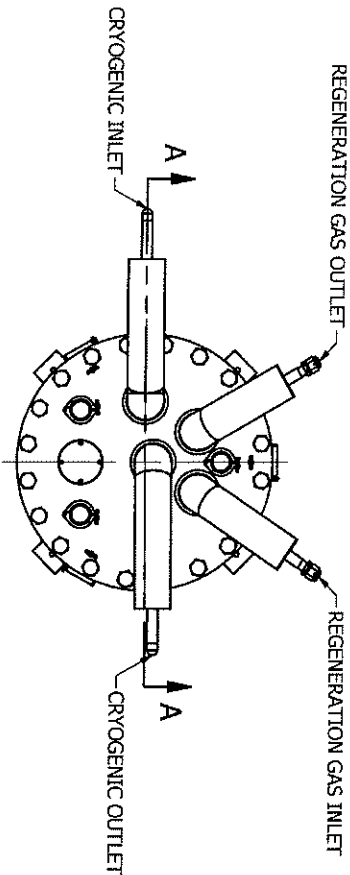
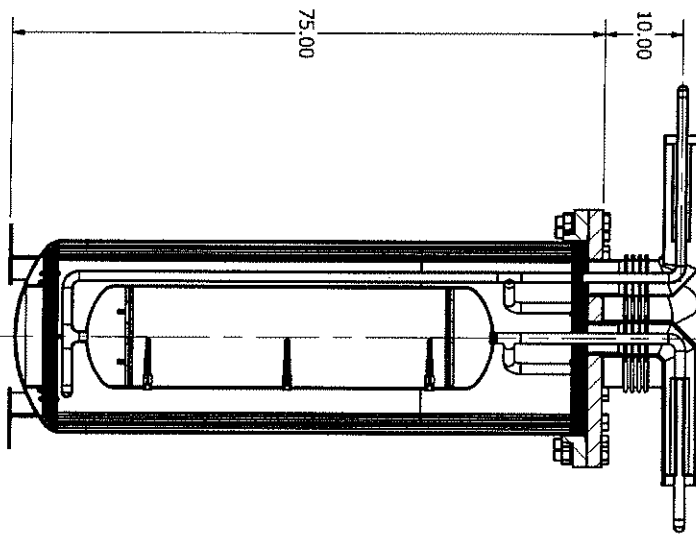
10-0214 2. ADDED ITEM 17: LABEL PART NO. BC-02128-1704.
10-0214 1. ADDED VESSEL TAGS TABLE.

REVISION OF DESCRIPTION

BC-02128
ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL

information Copy

SECTION A-A
SCALE 1 : 15



SCALE 1 : 25

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. MASS SPEC. OUTER VESSEL PER EDEN CRYOGENICS SPEC. BC-101-070-001.
3. PRESSURE INNER VESSEL AND PIPING TO 1 PSI WITH NITROGEN.
4. PRIOR TO SHIPMENT, INSTALL SHIPPING PLUGS BC-02128-5920.

REV	STATUS
1	SH
2	REV
3	A

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. ALL DIMENSIONS APPLY AFTER FINISH.
3. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
4. SURFACE TEXTURE/FINISH 54 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.



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PLAIN CITY, OH 43064
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OWN: MAB 10/15/2009
CHK: JHM 12/28/2009
ENGR: JHM 12/28/2009

APP: 09-0377


DATE: 12/28/2009

SCALE 1:15

SIZE	DRAWING/PAK1 NUMBER	SHEET	REV
B	BC-02128-5800-02	1 of 3	A

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
A	6/22/2010	MAB	10-0214	SEE SHEET 3 FOR REV A.	
BC-02128					
ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL					

Information Copy

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DWN: MAB 10/15/2009 CHKD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:			
		XREF: REV: DATE: CHANGED BY: ETO:		REVISION DESCRIPTION	
		TITLE:		BC-02128 ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL	

PARTS LIST					
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	1	BC-02128-5810	WELDMENT, VACUUM VESSEL		Welded Stainless Steel 304/304L
2	1	BC-02128-5815	FINAL ASSEMBLY, LAR PRESSURE VESSEL W/ PORTS		Welded Stainless Steel 304/304L
3	1	BC-02128-5890	ASSEMBLY, HEAT SHIELDS, BOTTOM		
4	1	BC-02128-5900	ASSEMBLY, HEAT SHIELDS, SIDE		
5	20	FA-020-812-006	HEX NUT, INCH, 1 1/4-7 UNC		Stainless Steel 304/304L ASTM A194 GR 8
6	20	FA-020-812-030	SPRING LOCK WASHER, 1 1/4		Stainless Steel 18-8
7	1	HW-001-001-474	VTION O-RING	2-474	Viton
8	20	FA-020-112-326	HEX BOLT, INCH, 1 1/4-7 UNC X 6 LG		Stainless Steel 304/304L ASTM A193 GR B8
9	6	710003	CENTERING RING, MDC VACUUM PRODUCTS		
10	6	712003	FLANGE, BLANK, NW50, MDC VACUUM PRODUCTS		Stainless Steel 304/304L
11	6	701003	CLAMP, HINGED, MDC VACUUM PRODUCTS		
12	1	HW-001-001-241	VTION O-RING	2-241	Viton
13	1	BC-02128-0103	PARALLEL PLATE RELIEF, TOP PLATE		Stainless Steel 304/304L ASTM A240
14	4	BC-02128-0104	LIFT PLATE, SPRING	9663K56	Stainless Steel 302
15	4	BC-02128-0105	SHOULDER SCREW, 5/16 Ø X 3 1/2, 1/4-20 UNC	90298A597	Stainless Steel 18-8
16	3	BC-02128-5920	SHIPPING PLUG		
17	1	BC-02128-1705	LABEL, CODED VESSEL, DUPLICATE	LB-003-000-001	Stainless Steel 304/304L

VESSEL TAGS			
SERIAL NO.	PRESSURE VESSEL LABEL	DUPLICATE LABEL	VACUUM VESSEL LABEL
02128-02	BC-02128-1702	BC-02128-1705	BC-02128-1708

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. ALL DIMENSIONS APPLY AFTER FINISH.
3. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
4. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
X.X ±.030
X.XX ±.010
X.XXX ±.005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CYBERGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CYBERGENICS, LLC.

OWN: MAR 10/18/2009
CHGR: JHM 12/28/2009
ENGR: JHM 12/28/2009

APPR:

EDR: 09-0377

DATE: 12/28/2009

SCALE:



8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.873.3949

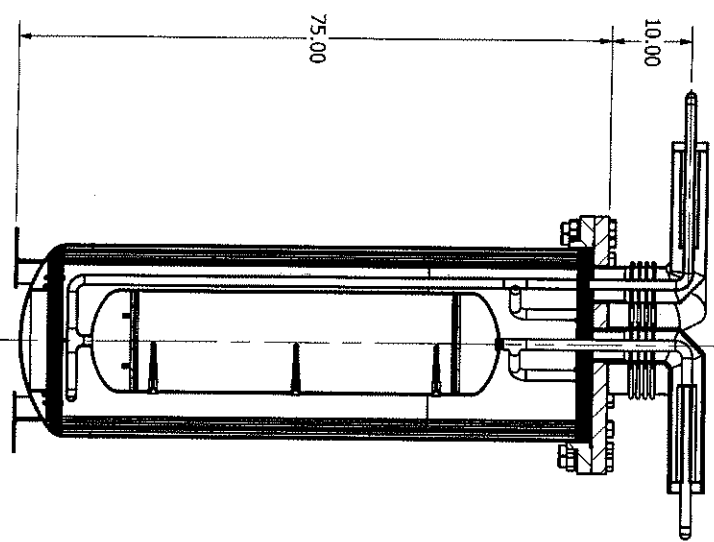
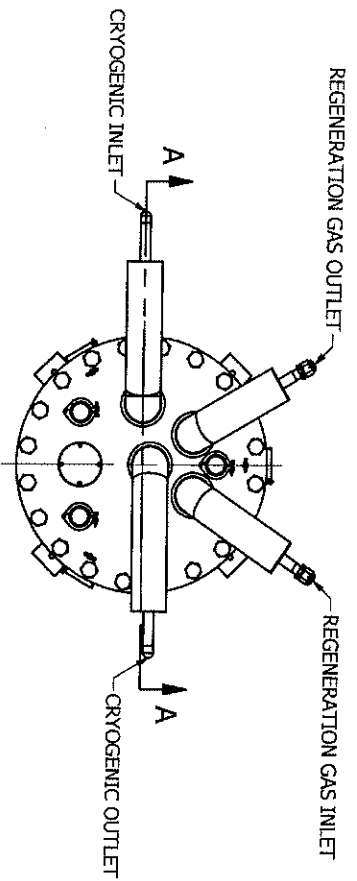
www.edencybergenics.com

SIZE	DRAWING/PART NUMBER	SHEET	REV
B	BC-02128-5800-02	3 OF 3	A

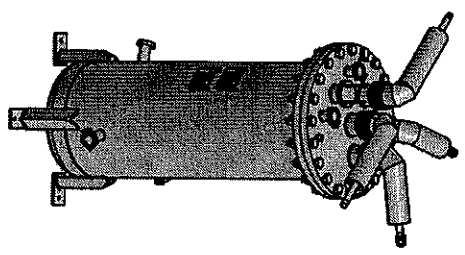
REV	DATE	BY	CHKD	APPD	DESCRIPTION
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05	6/22/2010	MAB			10-0214 1. ADDED VESSEL TAGS TABLE.
06	11/11/11	JHM			11-0009-01 BY JHM
TITLE					
BC-02128					
ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL					

Information Copy

4 3 2 1



SECTION A-A
SCALE 1 : 15



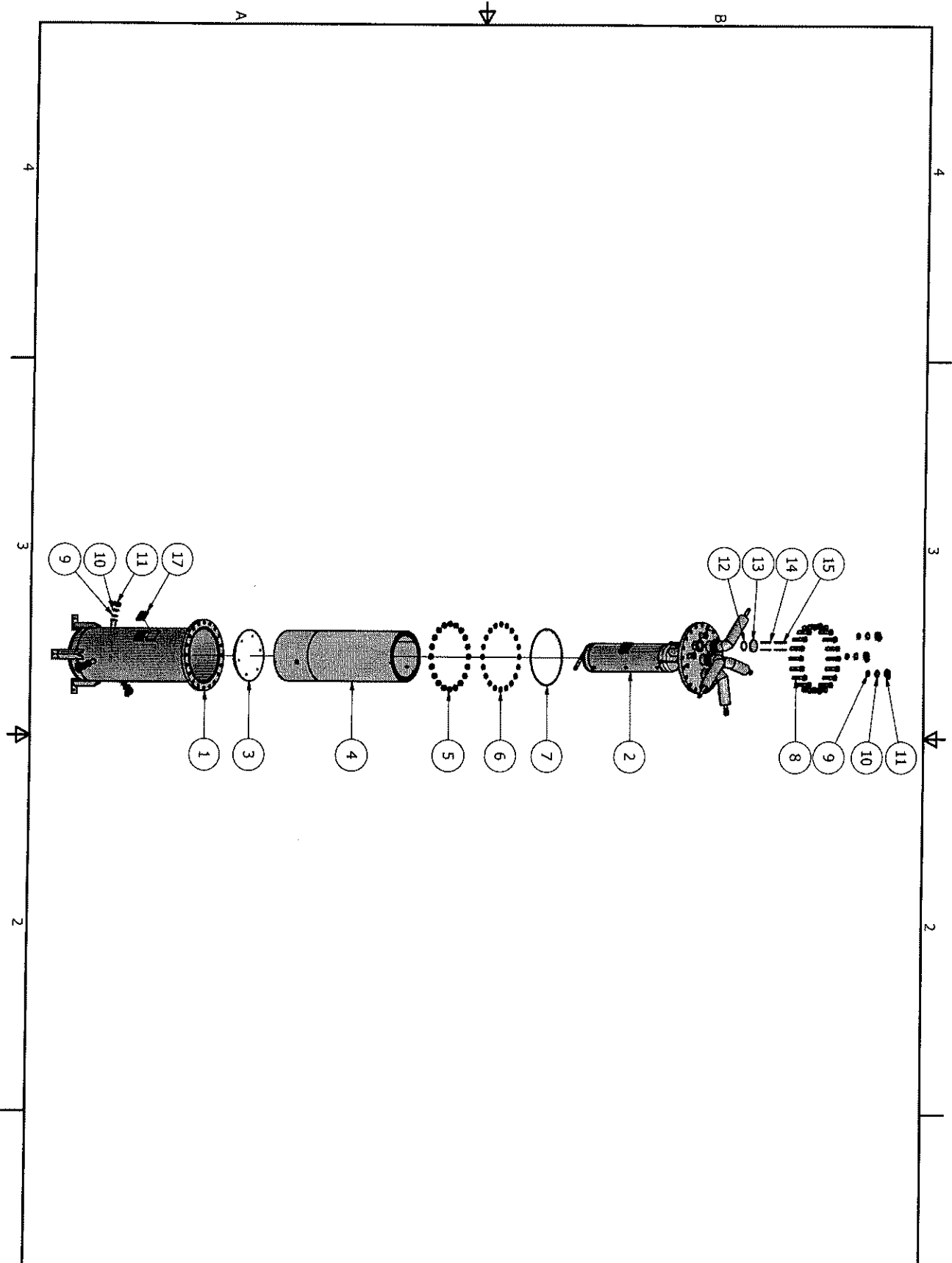
SCALE 1 : 25

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. MASS SPEC. OUTER VESSEL PER EDEN CRYOGENICS SPEC. BC-101-070-001.
3. PRESSURE INNER VESSEL AND PIPING TO 1 PSI WITH NITROGEN.
4. PRIOR TO SHIPMENT, INSTALL SHIPPING PLUGS BC-02128-5920.

REV STATUS	
SH	REV
1	A
2	-
3	A


NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 10/15/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHECKED: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2°		APPROVED:	
EDEN CRYOGENICS		8445 RAUSCH DRIVE		ZONE A 6/22/2010 MAB 10-0214 SEE SHEET 3 FOR REV A.	
PLAIN CITY, OH 43064		614.873.3949		CHANGED BY	
www.edencyrogenics.com		CDR: 09-0377		EDR	
SHEET 1 OF 3		DATE: 12/28/2009		REVISION DESCRIPTION	
REV A		SCALE: 1:15		BC-02128	
B		DRAWING/PART NUMBER		ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL	



NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN ORTHOGONICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN ORTHOGONICS, LLC.	
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edenorthogenics.com		DWR: MAB 10/15/2009 CHD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:40	
SIZE B	DRAWING/PART NUMBER BC-02128-5800-03	SHEET 2 of 3	REV -	TITLE ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL	

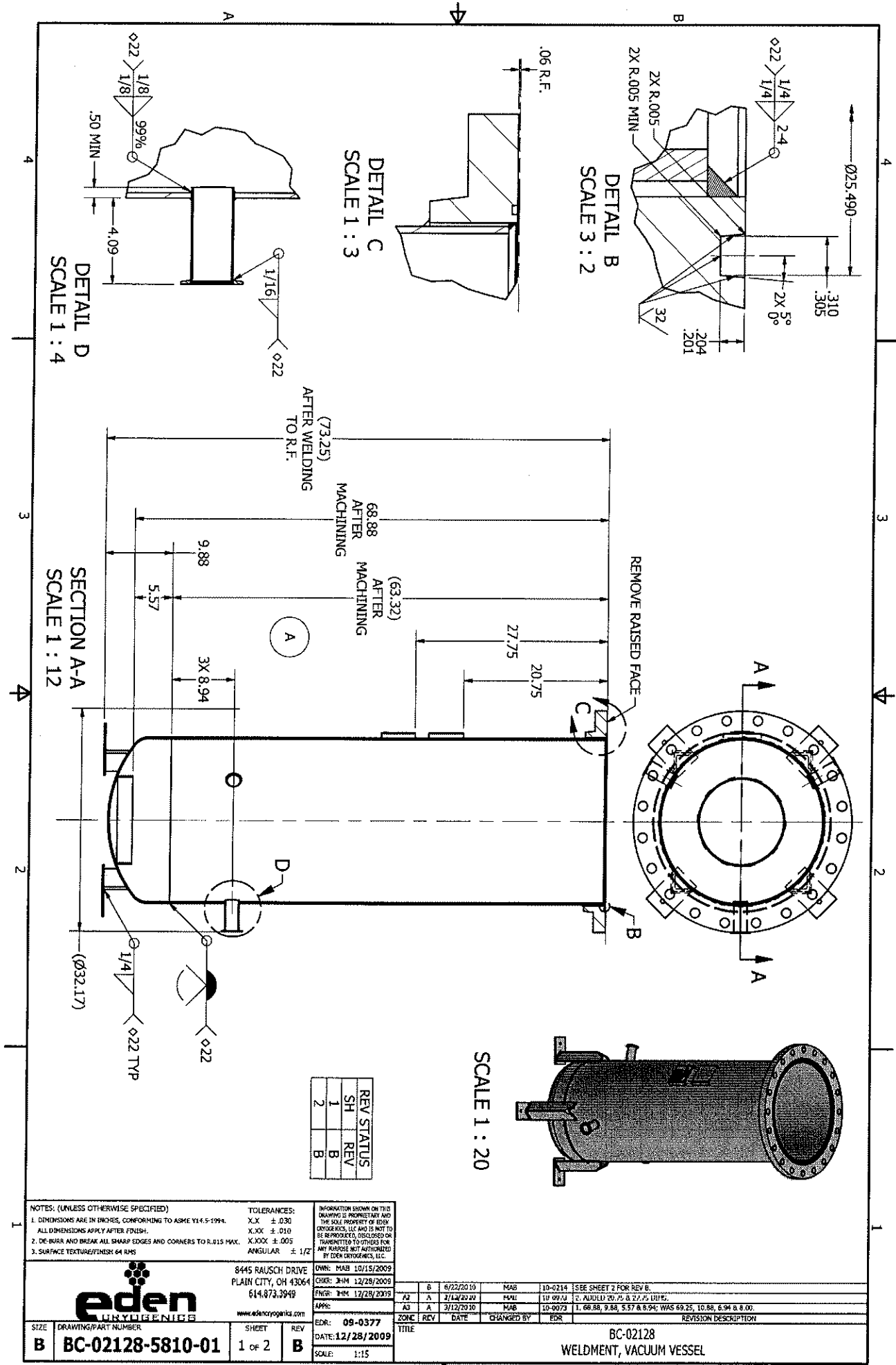
PARTS LIST			
ITEM/ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER
1 1	BC-02128-5810	WELDMENT, VACUUM VESSEL	
2 1	BC-02128-5815	FINAL ASSEMBLY, LAR PRESSURE VESSEL W/ PORTS	Welded Stainless Steel 304/304L
3 1	BC-02128-5890	ASSEMBLY, HEAT SHIELDS, BOTTOM	Welded Stainless Steel 304/304L
4 1	BC-02128-5900	ASSEMBLY, HEAT SHIELDS, SIDE	
5 20	FA-020-812-006	HEX NUT, INCH, 1 1/4-7 UNC	Stainless Steel 304/304L ASTM A194 GR 8
6 20	FA-020-812-030	SPRING LOCK WASHER, 1 1/4	Stainless Steel 18-8
7 1	HW-001-001-474	WITON O-RING	Witon
8 20	FA-020-112-326	HEX BOLT, INCH, 1 1/4-7 UNC X 6 LG	Stainless Steel 304/304L ASTM A193 GR B8
9 6	710003	CENTERING RING, MDC VACUUM PRODUCTS	
10 6	712003	FLANGE, BLANK, MW50, MDC VACUUM PRODUCTS	Stainless Steel 304/304L
11 6	701003	CLAMP, HINGED, MDC VACUUM PRODUCTS	
12 1	HW-001-001-241	WITON O-RING	Witon
13 1	BC-02128-0103	PARALLEL PLATE RELIEF, TOP PLATE	Stainless Steel 304/304L ASTM A240
14 4	BC-02128-0104	LIFT PLATE, SPRING	9663K56
15 4	BC-02128-0105	SHOULDER SCREW, 5/16 Ø X 3 1/2, 1/4-20 UNC	Stainless Steel 302
16 3	BC-02128-5920	SHIPPING PLUG	90298A597
17 1	BC-02128-1706	LABEL, CODED VESSEL, DUPLICATE	Stainless Steel 304/304L

VESSEL TAGS			
SERIAL NO.	PRESSURE VESSEL LABEL	DUPLICATE LABEL	VACUUM VESSEL LABEL
02128-03	BC-02128-1703	BC-02128-1706	BC-02128-1709

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyogenics.com		DWN: MAB 10/15/2009 CHN: JHM 12/28/2009 APP:		10-0214 2. ADDED ITEM 17: LABEL PART NO. BC 02128 1706. 10-0214 1. ADDED VESSEL TAGS TABLE.	
SIZE: B DRAWING/PART NUMBER: BC-02128-5800-03		SHEET: 3 OF 3 REV: A		EDR: 09-0377 DATE: 12/28/2009 SCALE:	

BC-02128
ASSEMBLY, LIQUID ARGON TPC PURITY DEMO PURIFIER VESSEL

Information Copy



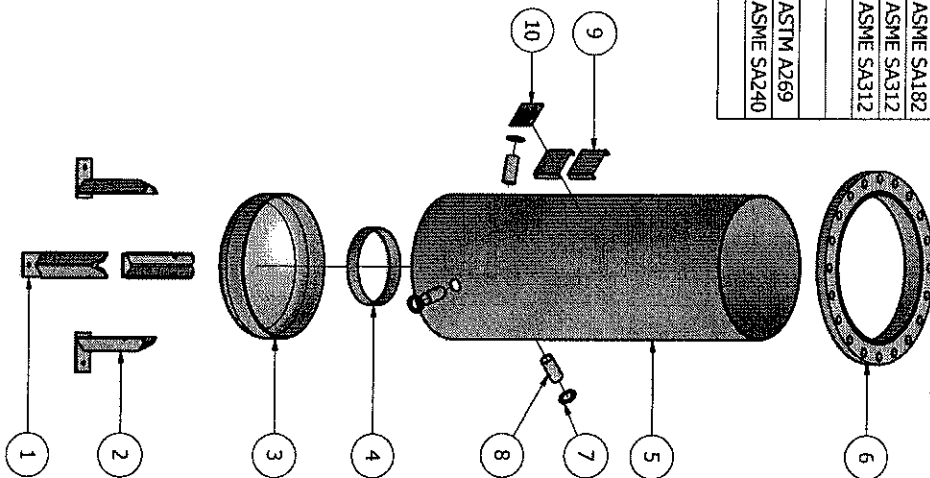
NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CYTOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CYTOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 10/15/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .010		CHKD: JHM 12/28/2009	
3. SURFACE TEXTURE/REQUIREMENT 64 RMS		X.XXXX ± .005		ENGR: JHM 12/28/2009	
		ANGULAR ± 1/2°		APPD:	
				EDR: 09-0377	
				DATE: 12/28/2009	
				SCALE: 1:15	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencytogenics.com		SHEET 1 OF 2		REV B	
SIZE B		DRAWING/PART NUMBER BC-02128-5810-01		TITLE BC-02128 WELDMENT, VACUUM VESSEL	

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
A2	B	6/22/2010	MAB	10-0214	SBE SHEET 2 FOR REV B.
A3	A	2/14/2010	MAB	10-0214	2. ADDED R.015 & 0.015 UTILS.
A3	A	3/12/2010	MAB	10-0073	1. 68.88, 9.84, 5.57 & 6.94; WAS 69.25, 10.88, 6.94 & 8.00.

Information Copy

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	4	BC-02128-0044	OUTER VESSEL, FEET
2	4	BC-02128-0049	OUTER VESSEL, ANGLE SUPPORT, 3 X 3 X 3/8 THK
3	1	BC-02128-0045	WELD CAP, 24 NPS X SCH 10
4	1	BC-02128-0039	SUPPORT, HEAT SHIELD, 12 NPS X SCH 10
5	1	BC-02128-0043	VACUUM VESSEL, PIPE, 24 NPS X SCH 10
6	1	FL-384-150-001	FLANGE, SLIP-ON RAISED FACE, 150#, 24 NPS
7	3	713022	FLANGE, WELD, NMSO, MDC VACUUM PRODUCTS
8	3	BC-02128-0111	PASS-THRU, TUBE, 2 OD X .065 WALL X 4 5/8 LG
9	2	LB-003-001-020	VESSEL BRACKET, CODED LABEL
10	1	BC-02128-1707	LABEL, CODED VESSEL, VACUUM VESSEL

B



NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. DRAWING IS FOR VACUUM VESSEL - 01.
3. MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
4. PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1. FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
5. "922" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
6. PASSIVATE ALL WELDS.
7. MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
8. INSPECT INNER SURFACES WITH ULTRA VIOLET LIGHT PER EDEN SPEC. BC-101-052-010, SECTION 13.2.
9. CERTIFIED TEST REPORTS AND TEST RECORD/DATA SHEETS SHALL BE PROVIDED TO THE PROJECT ENGINEER FOR THE FOLLOWING TESTS:
- 9.1. MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.

A

NOTES: (UNLESS OTHERWISE SPECIFIED)
 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
 2. ALL DIMENSIONS APPLY AFTER FINISH.
 3. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.005 MAX.
 4. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
 X.XX ±.030
 X.XXX ±.010
 X.XXXX ±.005
 ANGULAR ± 1/2°

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OWN: MAB 10/15/2009
 CHGR: JHM 12/28/2009
 ENGR: JHM 12/28/2009
 APPR:

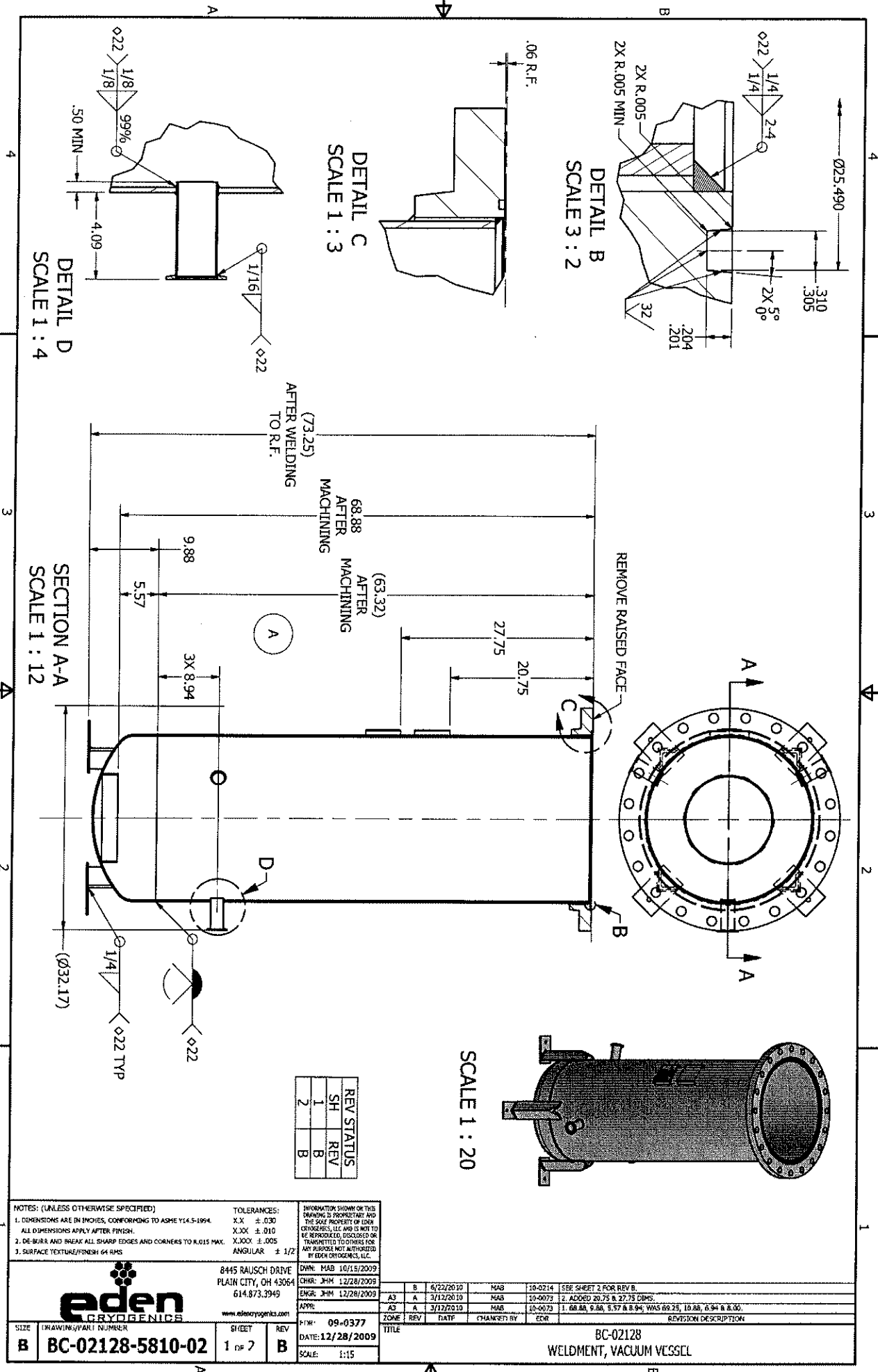
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 DATE: 12/28/2009
 SCALE: 1:25

ZONE	REV	DATE	CHANGED BY	EDR
B4	B	6/22/2010	MAB	10-0214
A3	A	3/12/2010	MAB	10-0073

ADDED ITEM 10: LABEL PART NO. BC-02128-1707.
 NOTE 2.1-01, WAS FOR -01, -02 & -03

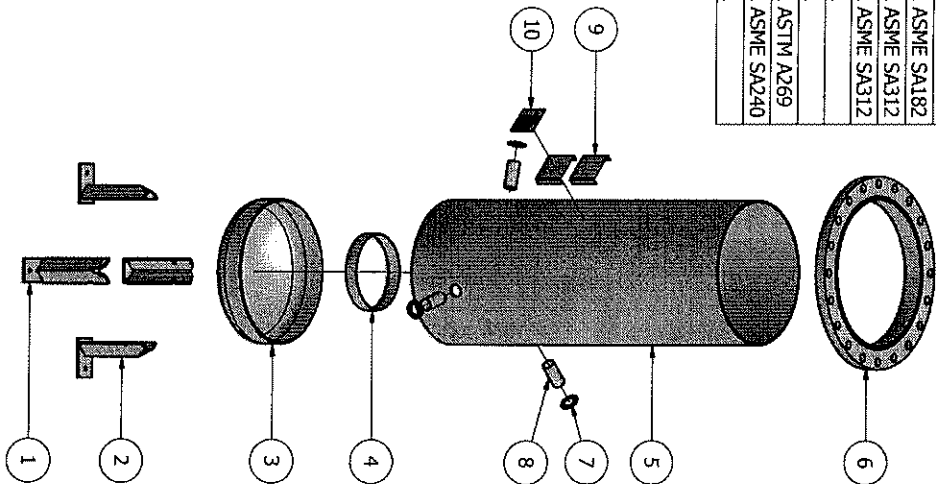
BC-02128
 WELDMENT, VACUUM VESSEL

Information Copy



PARTS LIST					
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	4	BC-02128-0044	OUTER VESSEL, FEET		Stainless Steel 304/304L ASME SA240
2	4	BC-02128-0049	OUTER VESSEL, ANGLE SUPPORT, 3 X 3 X 3/8 THK		Stainless Steel 304/304L ASME SA276
3	1	BC-02128-0045	WELD CAP, 24 NPS X SCH 10		Stainless Steel 304/304L ASME SA182
4	1	BC-02128-0039	SUPPORT, HEAT SHIELD, 12 NPS X SCH 10	PI-192-010-021	Stainless Steel 304/304L ASME SA312
5	1	BC-02128-0043	VACUUM VESSEL, PIPE, 24 NPS X SCH 10	PI-384-010-021	Stainless Steel 304/304L ASME SA312
6	1	FL-384-150-001	FLANGE, SLIP-ON RAISED FACE, 150#, 24 NPS		Stainless Steel 304/304L
7	3	713022	FLANGE, WELD, NWSQ, MDC VACUUM PRODUCTS		Stainless Steel 304/304L
8	3	BC-02128-0111	PASS-THRU, TUBE, 2 OD X .065 WALL X 4 5/8 LG	TU-032-065-031	Stainless Steel 304/304L ASTM A269
9	2	LB-003-001-020	VESSEL BRACKET, CODED LABEL		Stainless Steel 304/304L ASME SA240
10	1	BC-02128-1708	LABEL, CODED VESSEL, VACUUM VESSEL	LB-003-000-001	Stainless Steel 304/304L

B



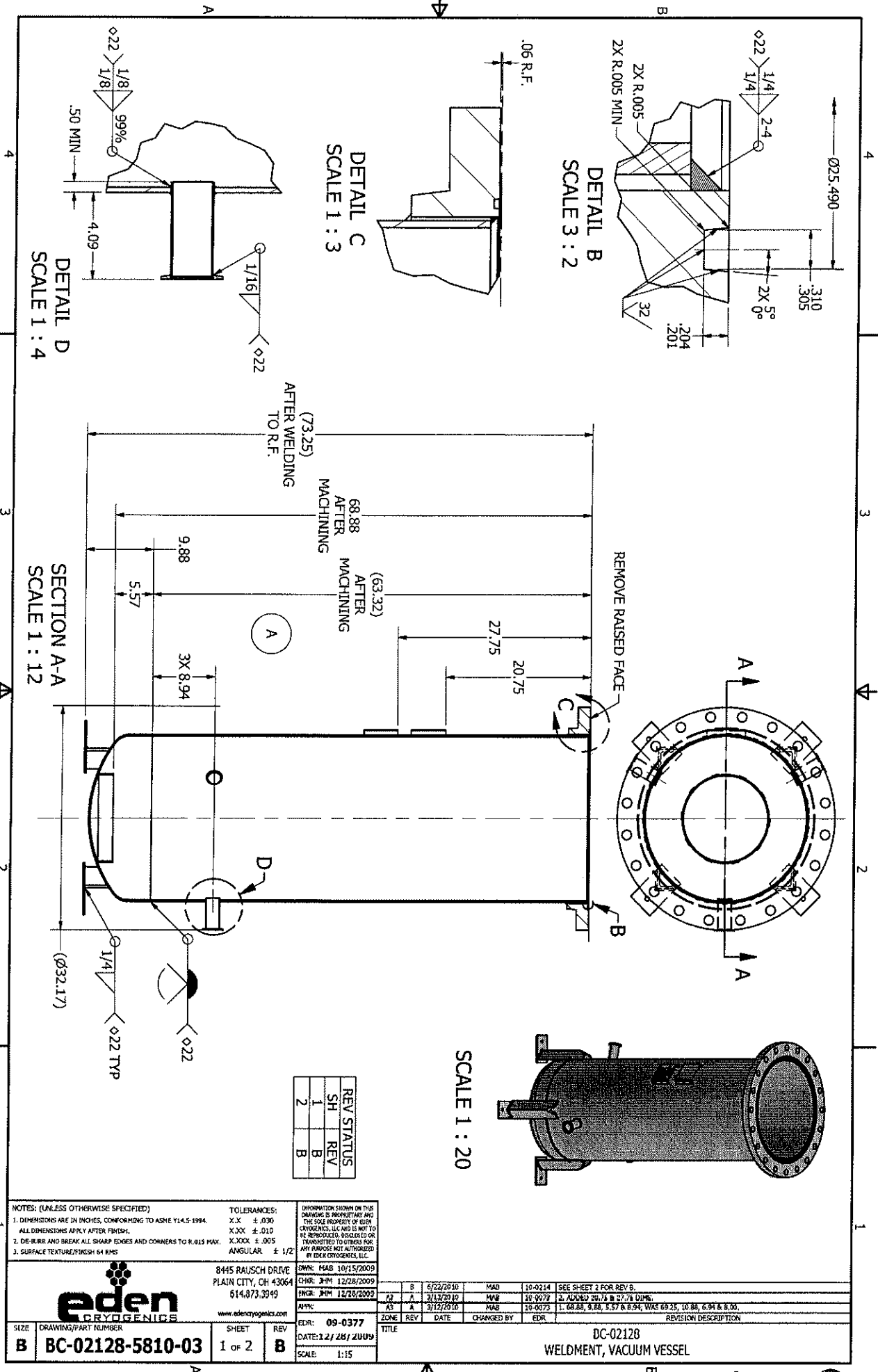
NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. DRAWING IS FOR VACUUM VESSEL - 02.
3. MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
4. PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1. FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
5. "022" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
6. PASSIVATE ALL WELDS.
7. MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
8. INSPECT INNER SURFACES WITH ULTRA VIOLET LIGHT PER EDEN SPEC. BC-101-052-010, SECTION 13.2.
9. CERTIFIED TEST REPORTS AND TEST RECORD/DATA SHEETS SHALL BE PROVIDED TO THE PROJECT ENGINEER FOR THE FOLLOWING TESTS:
- 9.1. MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.

A

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DWN: MAB 10/15/2009 CHN: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		10-0214 10-0073 10-0073	
SIZE: B DRAWING/PART NUMBER: BC-02128-5810-02		SHEET: 2 OF 2 REV: B		DATE: 12/28/2009 SCALE: 1:25	

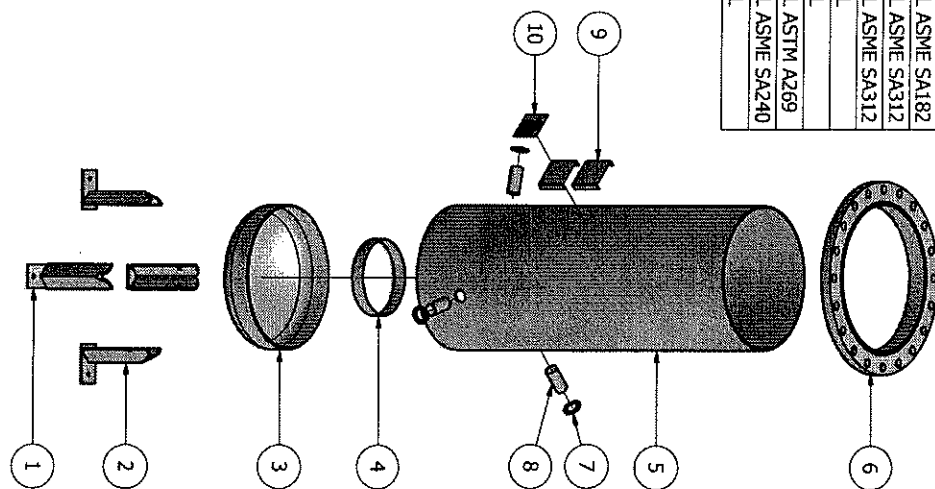
BC-02128
WELDMENT, VACUUM VESSEL



Information Copy

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	4	BC-02128-0044	OUTER VESSEL, FEET
2	4	BC-02128-0049	OUTER VESSEL, ANGLE SUPPORT, 3 X 3 X 3/8 THK
3	1	BC-02128-0045	WELD CAP, 24 NPS X SCH 10
4	1	BC-02128-0039	SUPPORT, HEAT SHIELD, 12 NPS X SCH 10
5	1	BC-02128-0043	VACUUM VESSEL, PIPE, 24 NPS X SCH 10
6	1	FL-384-150-001	FLANGE, SLIP-ON RAISED FACE, 150#, 24 NPS
7	3	713022	FLANGE, WELD, NW50, MDC VACUUM PRODUCTS
8	3	BC-02128-0111	PASS-THRU, TUBE, 2 OD X .065 WALL X 4 5/8 LG
9	2	LB-003-001-020	VESSEL BRACKET, CODED LABEL
10	1	BC-02128-1709	LABEL, CODED VESSEL, VACUUM VESSEL

8



NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. DRAWING IS FOR VACUUM VESSEL -03.
3. MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
4. PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1. FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
5. "0.022" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
6. PASSIVATE ALL WELDS.
7. MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001, SECTION 13.2.
8. INSPECT INNER SURFACES WITH ULTRA VIOLET LIGHT PER EDEN SPEC. BC-101-052-010, SECTION 13.2.
9. CERTIFIED TEST REPORTS AND TEST RECORD/DATA SHEETS SHALL BE PROVIDED TO THE PROJECT ENGINEER FOR THE FOLLOWING TESTS:
- 9.1. MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.

4

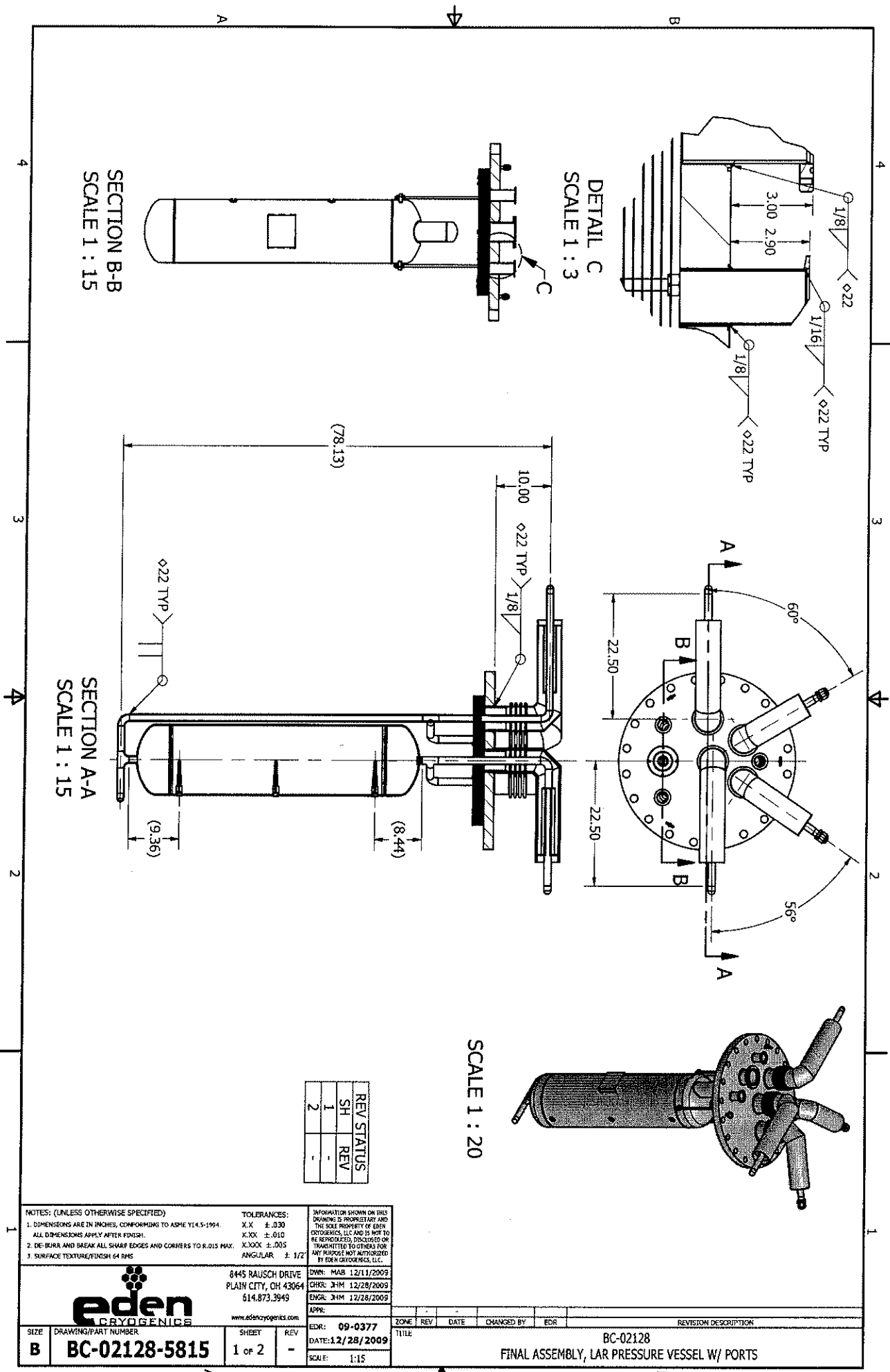
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2

1

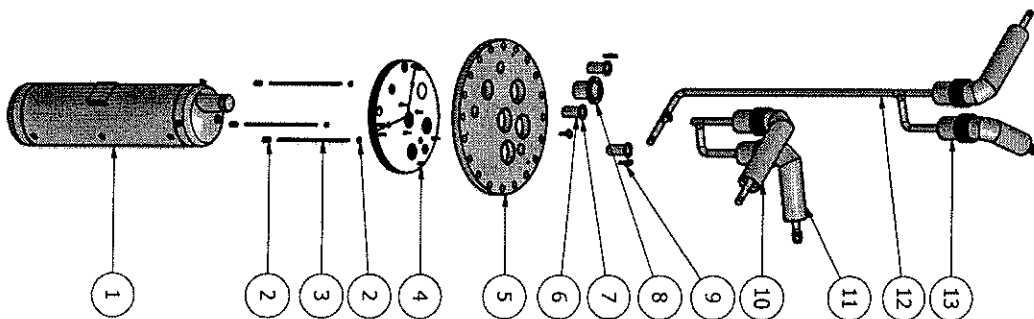
NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SCALE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWR: MAB 10/15/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XX ± .010		CHGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		X.XXX ± .005		ENGR: JHM 12/28/2009	
		ANGULAR ± 1/2°		APP:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DATE: 12/28/2009 EDR: 09-0377 SCALE: 1:25	
SZLZ	DRAWING/PART NUMBER	SHEET	REV	TITLE	
B	BC-02128-5810-03	2 OF 2	B	BC-02128 WELDMENT, VACUUM VESSEL	

Information Copy



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	BC-02128-5820	WELDMENT, LAR PRESSURE VESSEL
2	9	FA-008-812-006	HEX NUT - INCH 1/2 - .13 UNC
3	3	BC-02128-0123	ROD, ALL THREAD, 1/2-13 UNC X 18 LG
4	1	BC-02128-5910	ASSEMBLY, HEAT SHIELDS, TOP
5	1	BC-02128-0040	OUTER VESSEL, TOP FLANGE
6	3	BC-02128-0111	PASS-THRU, TUBE, 2 OD X .065 WALL X 4 5/8 LG
7	3	713022	FLANGE, WELD, NW50, MDC VACUUM PRODUCTS
8	1	BC-02128-5875	WELDMENT, PARALLEL PLATE RELIEF, BOTTOM
9	3	BC-02128-0121	EYEBOLT, 3/8-16 UNC, 1300#
10	1	BC-02128-5840	ASSEMBLY, CRYOGENIC OUTLET
11	1	BC-02128-5860	ASSEMBLY, REGENERATION GAS INLET
12	1	BC-02128-5830	ASSEMBLY, CRYOGENIC INLET
13	1	BC-02128-5850	ASSEMBLY, REGENERATION GAS OUTLET

- NOTE:**
- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
 - DRAWING IS FOR PRESSURE VESSELS -01, -02 & -03.
 - MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
 - PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1, FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
 - "0.22" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
 - RADIOGRAPHICALLY INSPECT 5% OF BUTT WELDS PER ANSI B31.3.
 - PERFORM MASS SPECTROMETER LEAK TEST (REF. BC101-050-010 SECTION 5.6.1).
 - PRESSURE TEST PER EDEN SPEC BC101-50-010 SECTION 5.6, DESIGN PRESSURE 150 PSIG.
 - TEST PRESSURE 188 PSIG.
 - FORWARD COPY OF TEST REPORT TO PROJECT ENGINEER.



NOTES: (UNLESS OTHERWISE SPECIFIED)

- DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
- ALL DIMENSIONS APPLY AFTER FINISH.
- DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
- SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
 X.X ±.030
 X.XX ±.010
 X.XXX ±.005
 ANGULAR ± 1/2°

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SIZE DRAWING/PART NUMBER
B BC-02128-5815

SHEET
 2 OF 2

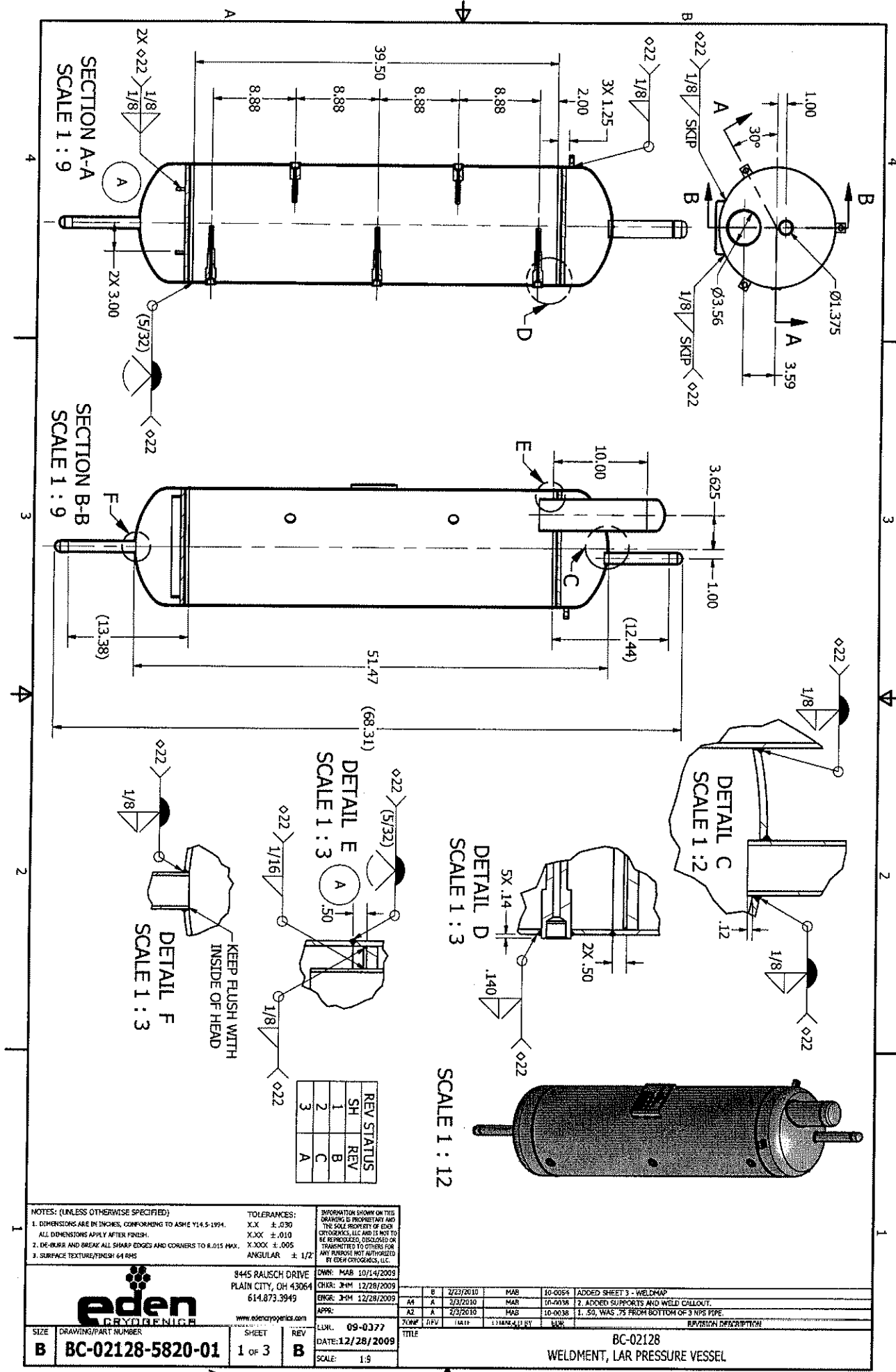
REV

CDR: 09-0377
 DATE: 12/28/2009
 SCALE: 1:25

TITLE

BC-02128
 FINAL ASSEMBLY, LAR PRESSURE VESSEL W/ PORTS

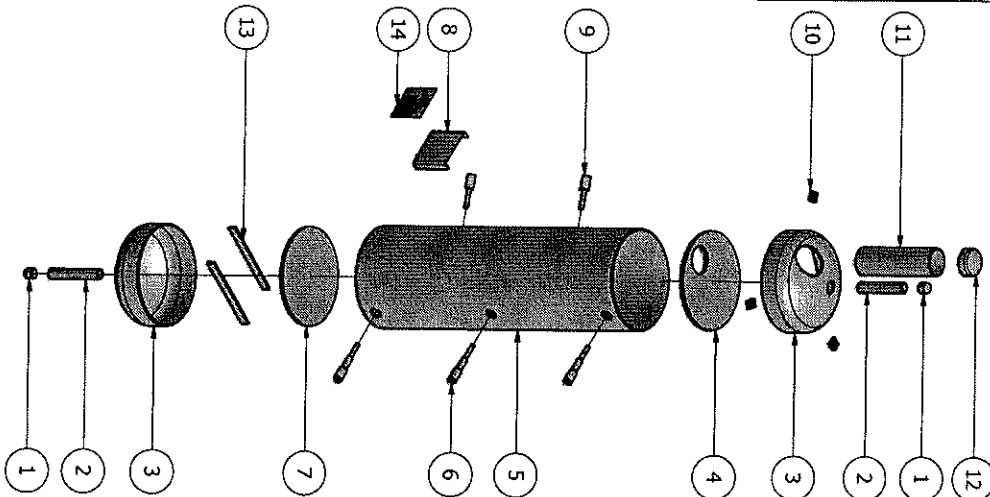
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Information Copy

ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	PO NO.	HEAT NO.	MATERIAL
1	2	BC-02128-0050	WELD CAP, 1 NPS X SCH 10		BC-3276	0181	Stainless Steel 304/304L, ASME SA182
2	2	BC-02128-0059	PIPE, 1 NPS X SCH 10 X 15 LG	PI-016-010-021	BC-3276	829979	Stainless Steel 304/304L, ASME SA312
3	2	BC-02128-0053	WELD CAP, 12 NPS X SCH 10		BC-3276	B8070055	Stainless Steel 304/304L, ASTM A403
4	1	BC-02128-0057	INNER VESSEL, GKN SINTERED METAL DISC	SIFA-R-30	BC-3279	A31775_10	ASTM 316L
5	1	BC-02128-0052	PRESSURE VESSEL, PIPE, 12 NPS X SCH 10	PI-192-010-021	BC-3283	280463	Stainless Steel 304/304L, ASME SA312
6	3	BC-02128-0055	THERMOWELL	1700-P-6	BC-3283	3C730	Stainless Steel 304/304L
7	1	BC-02128-0058	INNER VESSEL, GKN SINTERED METAL DISC	SIFA-R-30	BC-3279	A31775_20	ASTM 316L
8	1	LB-003-001-020	VESSEL BRACKET, CODED LABEL		BC-3453	5LV5	Stainless Steel 304/304L, ASME SA240
9	2	BC-02128-0056	BRACKET, HANGING SUPPORT	1700-P-4	BC-3283	3C730	Stainless Steel 304/304L, ASTM A240
10	3	BC-02128-0124	INNER VESSEL, PIPE, 3 NPS X SCH 10 X 11 1/2 LG	PI-048-010-021	BC-3175	231105	Stainless Steel 304/304L, ASTM A240
11	1	BC-02128-0051	WELD CAP, 3 NPS X SCH 10		BC-3276	391025	Stainless Steel 304/304L, ASME SA312
12	1	BC-02128-0054	SUPPORT, SINTERED METAL, 1/4 X 1 X 11 LG		BC-3276	139308	Stainless Steel 304/304L, ASTM A403
13	2	BC-02128-0075	SUPPORT, SINTERED METAL, 1/4 X 1 X 11 LG		BC-3427	156654/	Stainless Steel 304/304L, ASME SA479
14	1	BC-02128-1701	LABEL, CODED VESSEL	LB-003-000-001		252208	Stainless Steel 304/304L

- NOTE:**
- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
 - VESSEL TO BE BUILT TO BOILER & PRESSURE CODE ASME SECTION VIII DIVISION 1.
 - MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
 - PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1. FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
 - "Ø22" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
 - PASSIVATE ALL WELDS.
 - DESIGN PRESSURE 150 PSIG, PNEUMATIC TEST PRESSURE 165 PSIG.
 - MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
 - INSPECT INNER SURFACES WITH ULTRA VIOLET LIGHT PER EDEN SPEC. BC-101-052-010, SECTION 13.2.
 - CERTIFIED TEST REPORTS AND TEST RECORD/DATA SHEETS SHALL BE PROVIDED TO THE PROJECT ENGINEER FOR THE FOLLOWING TESTS:
 - MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
 - ATTACH LABEL BC-02128-1701 AFTER A.I. INSPECTION.



NOTES: (UNLESS OTHERWISE SPECIFIED)

- DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
- ALL DIMENSIONS APPLY AFTER FINISH.
- DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
- SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
 X.X ± .030
 X.XX ± .010
 X.XXX ± .005
 ANGULAR ± 1/2°

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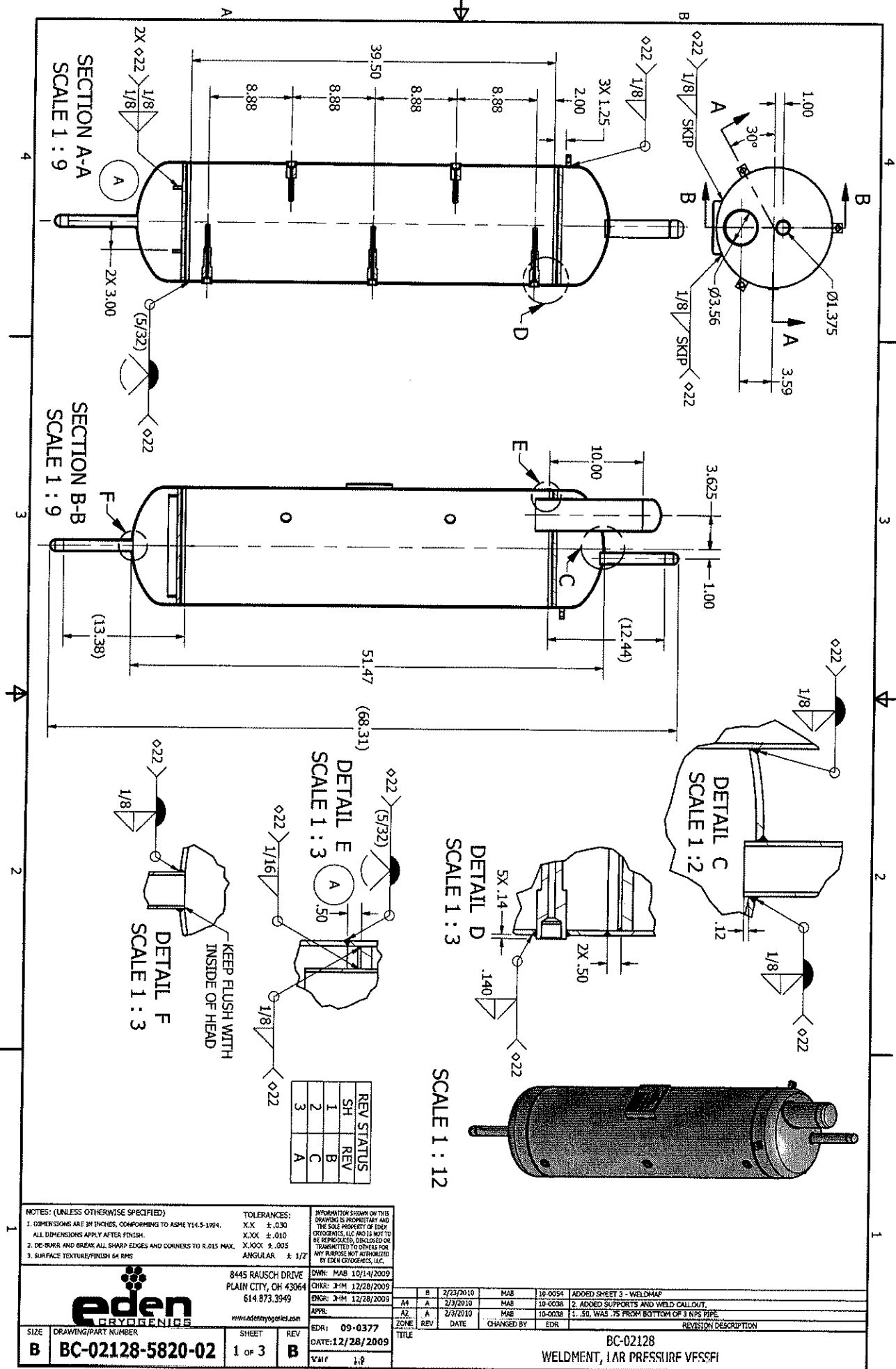
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 CHDR: JHM 12/28/2009
 ENGR: JHM 12/28/2009
 APPR:

EDR: 09-0377
 DATE: 12/28/2009
 SCALE: 1:15

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
A3	C	3/23/2010	MAB	10-0080	1. ADDED NOTE 11, ATTACH LABEL
B4	C	3/23/2010	MAB	10-0080	2. ADDED ITEM 14, CODED VESSEL LABEL
B3	C	3/23/2010	MAB	10-0080	1. ADDED PO NO. AND HEAT NO. 6.
A2	B	2/23/2010	MAB	10-0054	CHANGED NOTE 2, PREVIOUSLY SAID THE DRAWING WAS FOR VESSELS -01, -02, & -03.
B4	A	2/23/2010	MAB	10-0038	ADDED ITEM 13: BC-02128-0075.

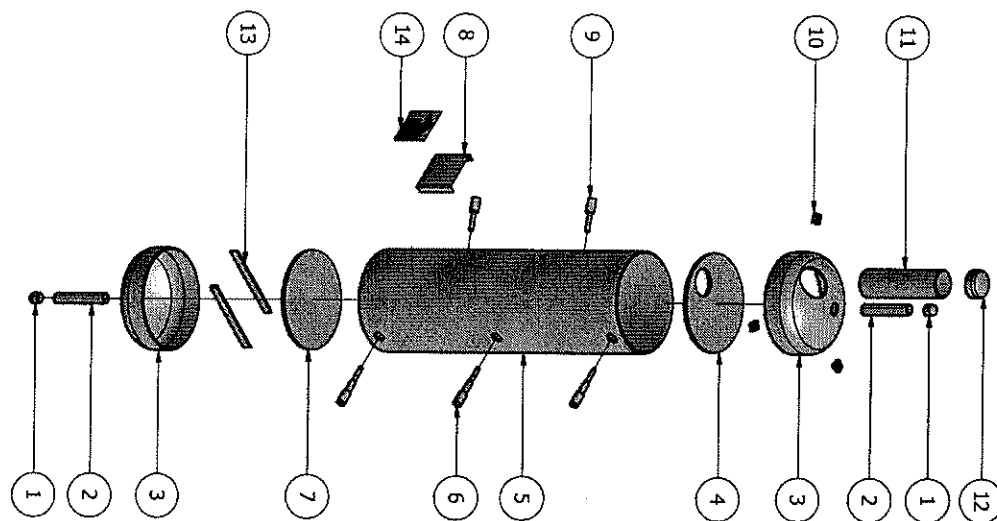
BC-02128
 WELDMENT, LAR PRESSURE VESSEL





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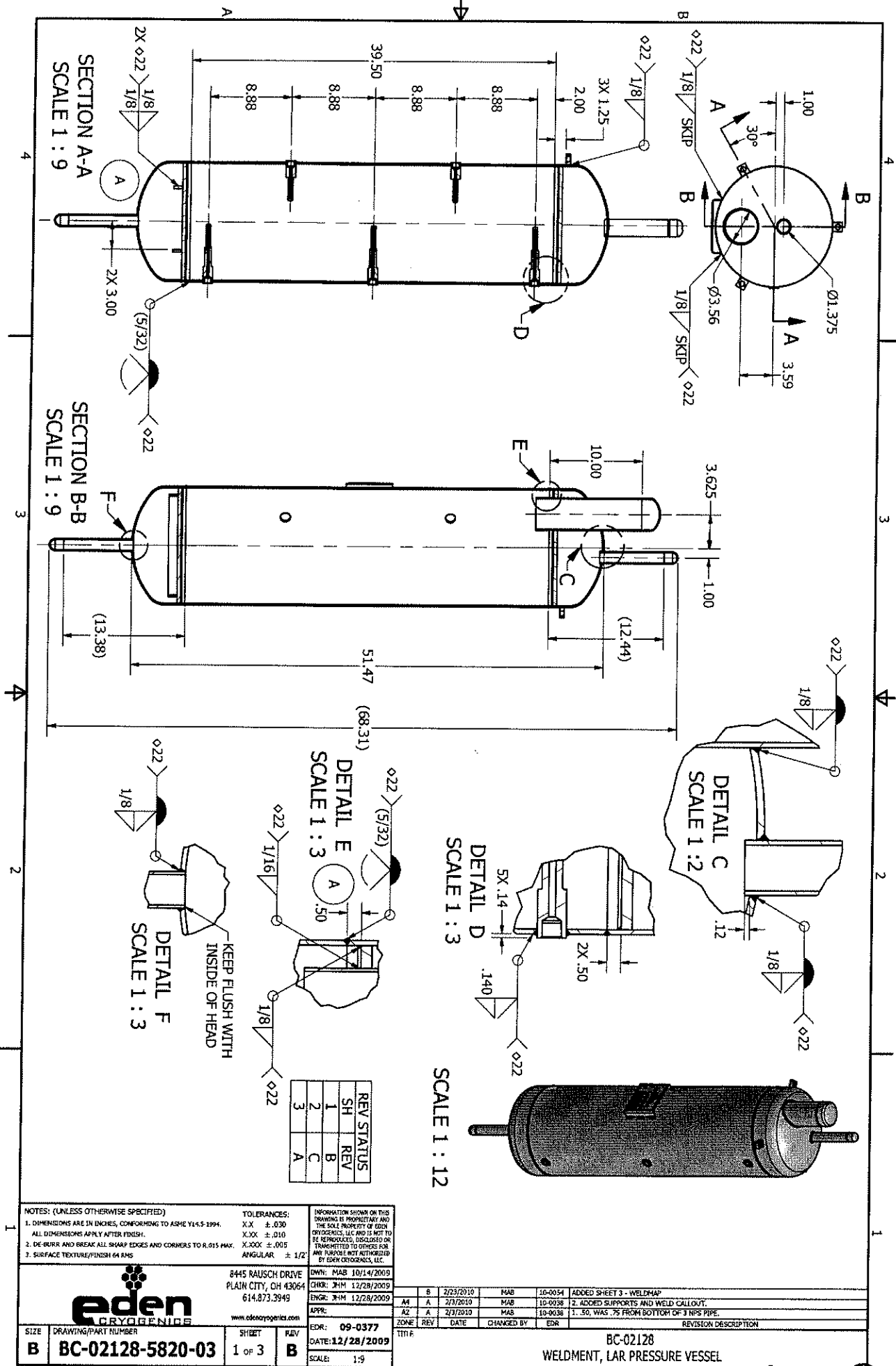
ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	PO NO.	HEAT NO.	MATERIAL
1	2	BC-02128-0050	WELD CAP, 1 NPS X SCH 10		BC-3276	0181	Stainless Steel 304/304L, ASME SA182
2	2	BC-02128-0059	PIPE, 1 NPS X SCH 10 X 15 LG	PI-016-010-021	BC-3276	829979	Stainless Steel 304/304L, ASME SA312
3	2	BC-02128-0053	WELD CAP, 12 NPS X SCH 10		BC-3276	88000055	Stainless Steel 304/304L, ASTM A403
4	1	BC-02128-0057	INNER VESSEL, GKN SINTERED METAL DISC		BC-3279	A317725_10	ASTI 316L
5	1	BC-02128-0052	PRESSURE VESSEL, PIPE, 12 NPS X SCH 10		BC-3276	280463	Stainless Steel 304/304L, ASME SA312
6	3	BC-02128-0055	THERMOWELL		BC-3279	30730	Stainless Steel 304/304L, ASME SA312
7	1	BC-02128-0058	INNER VESSEL, GKN SINTERED METAL DISC		BC-3283	A317725_20	ASTI 316L
8	1	LB-003-001-020	VESSEL, BRACKET, CODED LABEL		BC-3453	SLVS	Stainless Steel 304/304L, ASME SA240
9	2	BC-02128-0056	THERMOWELL		BC-3283	30730	Stainless Steel 304/304L
10	3	BC-02128-0124	BRACKET, HANGING SUPPORT	1700-P-4	BC-3175	231105	Stainless Steel 304/304L, ASTM A240
11	1	BC-02128-0051	INNER VESSEL, PIPE, 3 NPS X SCH 10 X 11 1/2 LG	PI-048-010-021	BC-3276	391025	Stainless Steel 304/304L, ASME SA312
12	1	BC-02128-0054	WELD CAP, 3 NPS X SCH 10		BC-3276	139308	Stainless Steel 304/304L, ASTM A403
13	2	BC-02128-0075	SUPPORT, SINTERED METAL, 1/4 X 1 X 11 LG		BC-3427	156654/	Stainless Steel 304/304L, ASME SA479
14	1	BC-02128-1702	LABEL, CODED VESSEL	LB-003-000-001		252208	Stainless Steel 304/304L




NOTE:

- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
- VESSEL TO BE BUILT TO BOILER & PRESSURE CODE ASME SECTION VIII DIVISION I.
- MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
- PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1. FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
- "O-22" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
- PASSIVATE ALL WELDS.
- DESIGN PRESSURE 150 PSIG, PNEUMATIC TEST PRESSURE 165 PSIG.
- MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
- INSPECT INNER SURFACES WITH ULTRA VIOLET LIGHT PER EDEN SPEC. BC-101-052-010, SECTION 13.2.
- CERTIFIED TEST REPORTS AND TEST RECORD/DATA SHEETS SHALL BE PROVIDED TO THE PROJECT ENGINEER FOR THE FOLLOWING TESTS:
 - MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
 - ATTACH LABEL BC-02128-1702 AFTER A.I. INSPECTION.

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH: 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CRYOGENICS, LLC. DWN: MAB 10/14/2009 CHDR: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:		10-0080 2. ADDED NOTE 11, ATTACH LABEL. 10-0080 2. ADDED ITEM 14, CODED VESSEL LABEL. 10-0080 1. ADDED PO NO.'S AND HEAT NO.'S. 10-0054 CHANGED HOT 2, PREVIOUSLY SAID THE DRAWING WAS FOR VESSEL -01, -02, & -03. 10-0038 ADDED ITEM 13: BC-02128-0075.	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.673.3949 eden CRYOGENICS www.edencyrogenics.com		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:15		TITLE BC-02128 WELDMENT, LAR PRESSURE VESSEL		REVISION DESCRIPTION	
SIZE B	DRAWING/PART NUMBER BC-02128-5820-02	SHEET: 2 OF 3	REV C				



NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWG: MAB 10/14/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2°		APP: _____	
				EDR: 09-0377	
				DATE: 12/28/2009	
				SCALE: 1:9	

 <div>8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949</div> <div>www.edencyogenics.com</div>		<div>DWYN: MAB 10/14/2009 CHKD: JHM 12/28/2009 APPR: JHM 12/28/2009 EPOCH:</div>	
SIZE	DRAWING/PART NUMBER	SHEET	REV
B	BC-02128-5820-03	1 OF 3	B
		<div>EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:9</div>	

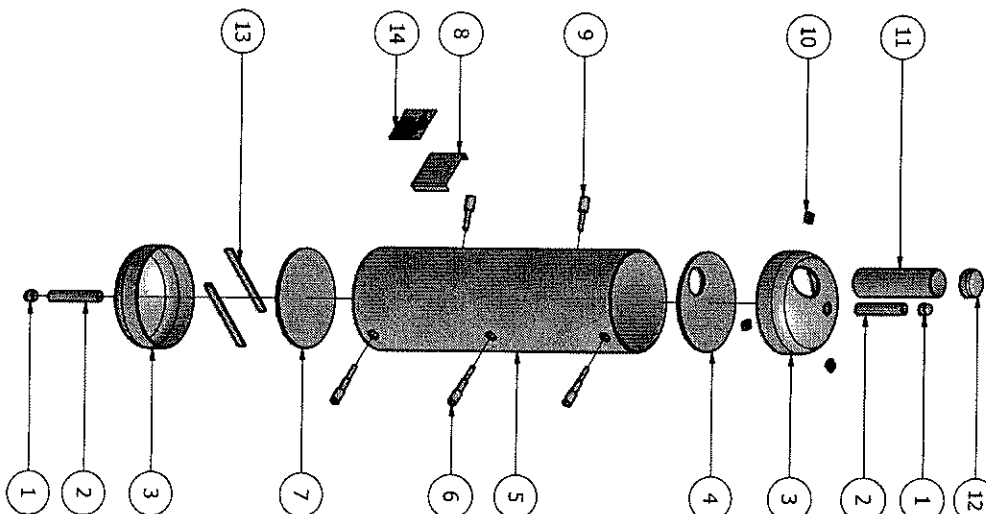
ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
A1	B	2/23/2010	MAB	10-0054	ADDED SHEET 3 - WELDMAP
A2	A	2/3/2010	MAB	10-0038	2. ADDED SUPPORTS AND WELD CALLOUT.
				10-0038	1. .50, WAS .75 FROM BOTTOM OF 3 NPS PIPE.

Information Copy

ITEM	QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	PO NO.	HEAT NO.	MATERIAL
1	2	BC-02128-0050	WELD CAP, 1 NPS X SCH 10		BC-3276	0181	Stainless Steel 304/304L, ASME SA182
2	2	BC-02128-0059	PIPE, 1 NPS X SCH 10 X 11 LG	PT-016-010-021	BC-3276	829979	Stainless Steel 304/304L, ASME SA312
3	2	BC-02128-0053	WELD CAP, 12 NPS X SCH 10		BC-3276	BB070055	Stainless Steel 304/304L, ASTM A403
4	1	BC-02128-0057	INNER VESSEL, GKN SINTERED METAL DISC		BC-3279	A317725.10	AISI 316L
5	1	BC-02128-0052	PRESSURE VESSEL, PIPE, 12 NPS X SCH 10		BC-3276	280463	Stainless Steel 304/304L, ASME SA312
6	3	BC-02128-0055	THERMOWELL	1700-P-6	BC-3283	3C730	Stainless Steel 304/304L
7	1	BC-02128-0058	INNER VESSEL, GKN SINTERED METAL DISC		BC-3279	A317725.20	AISI 316L
8	1	LB-003-001-020	VESSEL BRACKET, CODED LABEL		BC-3453	SLV5	Stainless Steel 304/304L, ASME SA240
9	2	BC-02128-0056	THERMOWELL	1700-P-4	BC-3283	3C730	Stainless Steel 304/304L
10	3	BC-02128-0124	BRACKET, HANGING SUPPORT		BC-3175	231105	Stainless Steel 304/304L, ASTM A240
11	1	BC-02128-0051	INNER VESSEL, PIPE, 3 NPS X SCH 10 X 11 1/2 LG	PT-048-010-021	BC-3276	391035	Stainless Steel 304/304L, ASME SA312
12	1	BC-02128-0054	WELD CAP, 3 NPS X SCH 10		BC-3276	139308	Stainless Steel 304/304L, ASTM A403
13	2	BC-02128-0075	SUPPORT, SINTERED METAL, 1/4 X 1 X 11 LG		BC-3427	156554/252208	Stainless Steel 304/304L, ASME SA479
14	1	BC-02128-1702	LABEL, CODED VESSEL	LB-003-000-001			Stainless Steel 304/304L

NOTE:

- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
- VESSEL TO BE BUILT TO BOILER & PRESSURE CODE ASME SECTION VIII DIVISION I.
- MATERIAL CERTS REQUIRED ON ALL ITEMS. (DELIVER TO PROJECT ENGINEER).
- PRE-CLEAN ALL SURFACES PRIOR TO FABRICATION PER SPEC. BC-101-052-010 SECTIONS 11.0, 4.1. FINAL CLEANING SHALL BE PERFORMED USING ETHYL ALCOHOL & A LINT FREE CLOTH.
- 5/32" WELD PER EDEN SPEC BC-101-001-022, LATEST REV.
- PASSIVATE ALL WELDS.
- DESIGN PRESSURE 150 PSIG, PNEUMATIC TEST PRESSURE 165 PSIG.
- MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
- INSPECT INNER SURFACES WITH ULTRA VIOLET LIGHT PER EDEN SPEC. BC-101-052-010, SECTION 13.2.
- CERTIFIED TEST REPORTS AND TEST RECORD/DATA SHEETS SHALL BE PROVIDED TO THE PROJECT ENGINEER FOR THE FOLLOWING TESTS:
 - MASS SPEC. PER EDEN CRYOGENICS SPEC. BC-101-070-001.
 - ATTACH LABEL BC-02128-1702 AFTER A.I. INSPECTION.



NOTES: (UNLESS OTHERWISE SPECIFIED)

- DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
- ALL DIMENSIONS APPLY AFTER FINISH.
- DIC BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
- SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
 X.X ±.030
 X.XX ±.010
 X.XXX ±.005
 ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.

OWN: MAB 10/14/2009
 CHG: JHM 12/28/2009
 ENGR: JHM 12/28/2009
 APPR:

ZONE	REV	DATE	CHANGED BY	EDR
A3	C	3/22/2010	MAB	10-0080
B4	C	3/22/2010	MAB	10-0080
A3	B	2/23/2009	MAB	10-0080
B4	A	2/23/2009	MAB	10-0080

REVISION DESCRIPTION
1. ADDED NOTE 11, ATTACH LABEL.
2. ADDED ITEM 14, CODED VESSEL LABEL.
3. ADDED PO NO. 8 AND HEAT NO. 5.
4. CHANGED NOTE 2, PREVIOUSLY SAID THE DRAWING WAS FOR VESSEL -01, -02, & -03.
ADDED ITEM 13: BC-02128-0075.

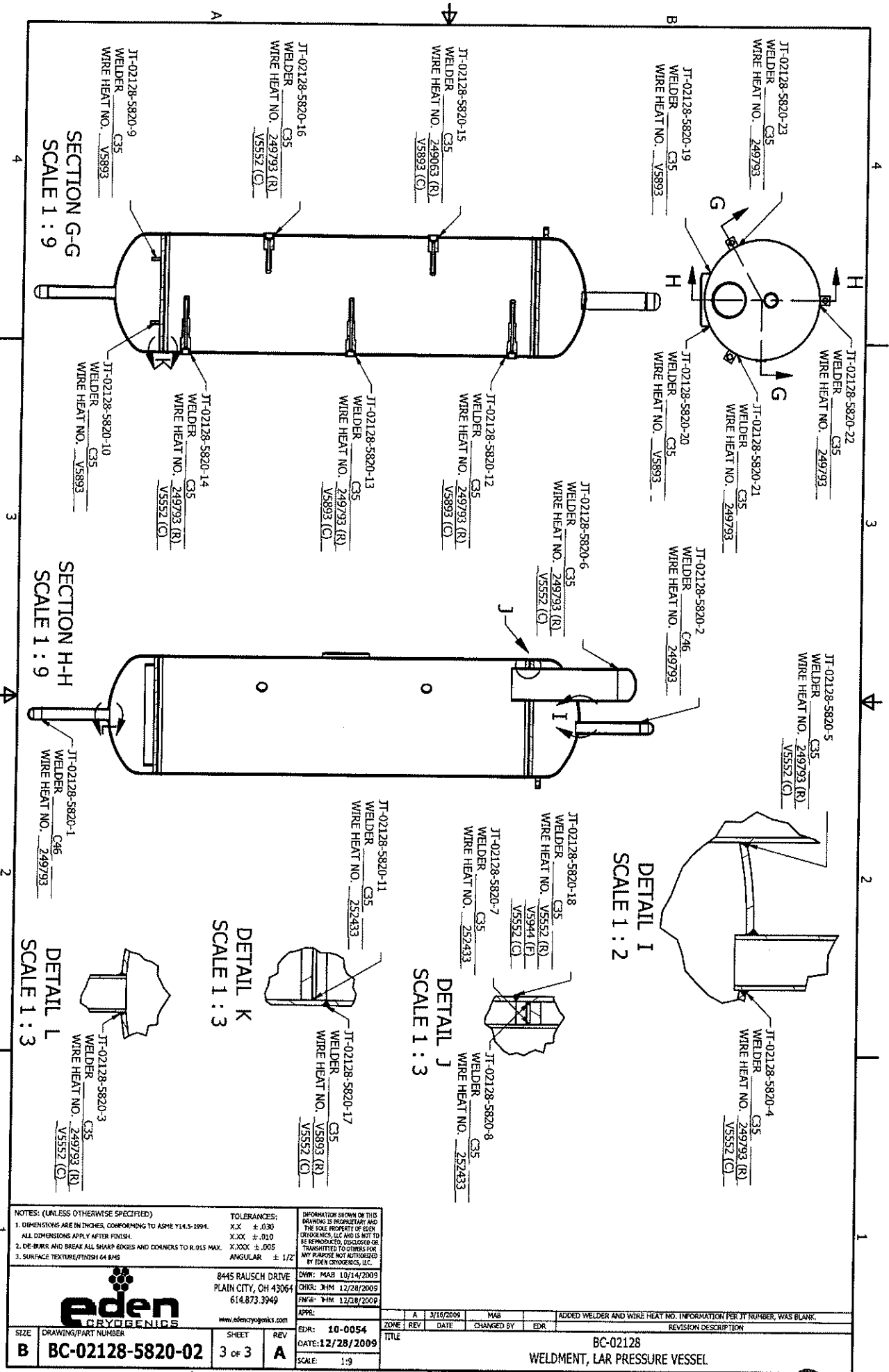
8445 RAUSCH DRIVE
 PLAIN CITY, OH 43064
 614.873.3949
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SIZE B DRAWING/PART NUMBER BC-02128-5820-02
 SHEET 2 OF 3
 REV C

EDR: 09-0377
 DATE: 12/28/2009
 SCALE: 1:15

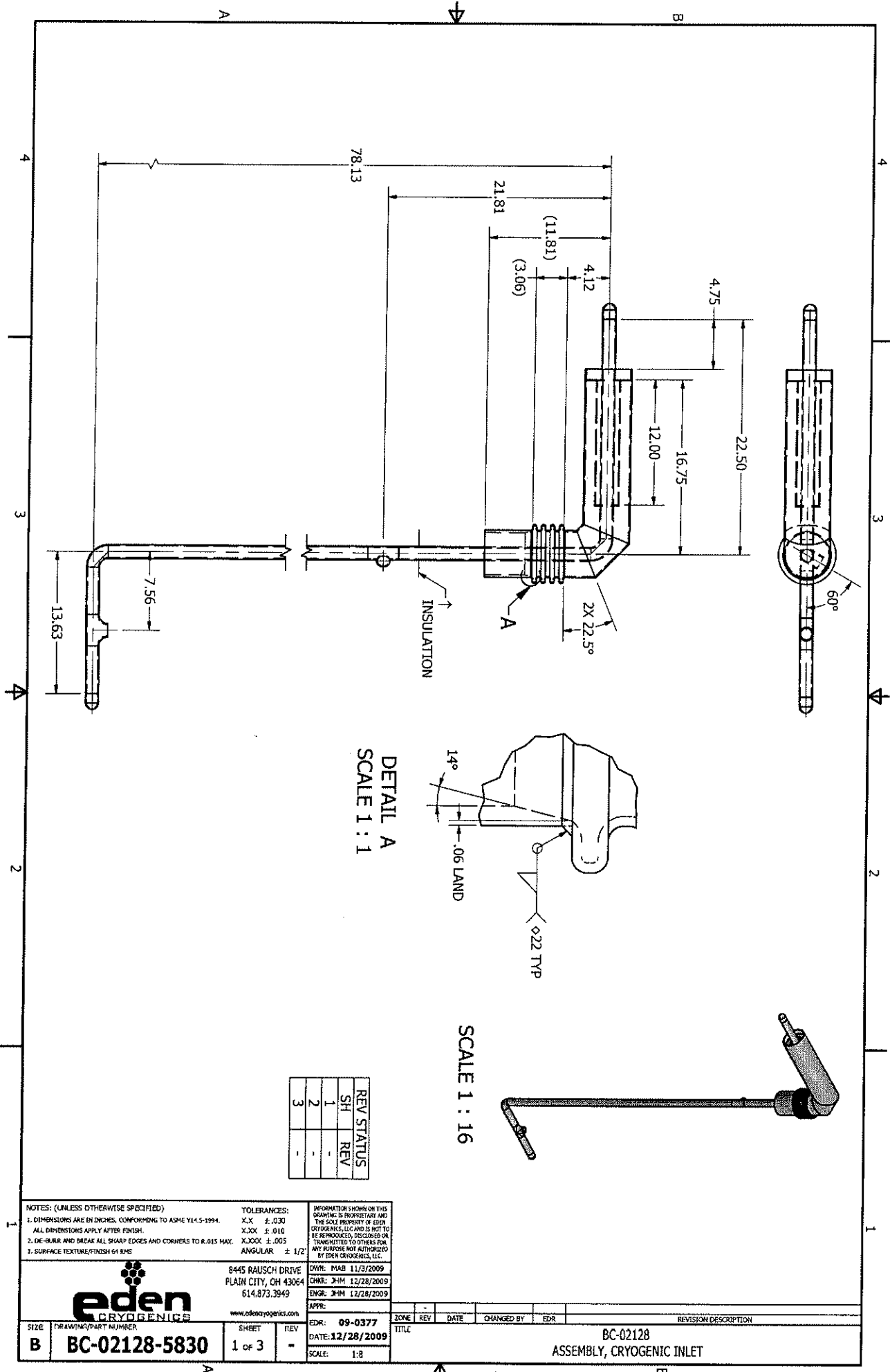
TITLE BC-02128
 WELDMENT, LAR PRESSURE VESSEL

Information Copy



NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.XX ± .030		DWG: MAB 10/14/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		FWG: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPR:	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		EDEN CRYOGENICS		EDR: 10-0054	
SHEET 3 OF 3		REV A		DATE: 12/28/2009	
SIZE B		DRAWING/PART NUMBER BC-02128-5820-02		SCALE: 1:9	
ZONE		REV		DATE	
A		3/15/2009		MAB	
REV		DATE		CHANGED BY	
TITLE		BC-02128		WELDMENT, LAR PRESSURE VESSEL	
ADDED WELDER AND WIRE HEAT NO. INFORMATION PER JT NUMBER, WAS BLANK.		REVISION DESCRIPTION			

Information Copy

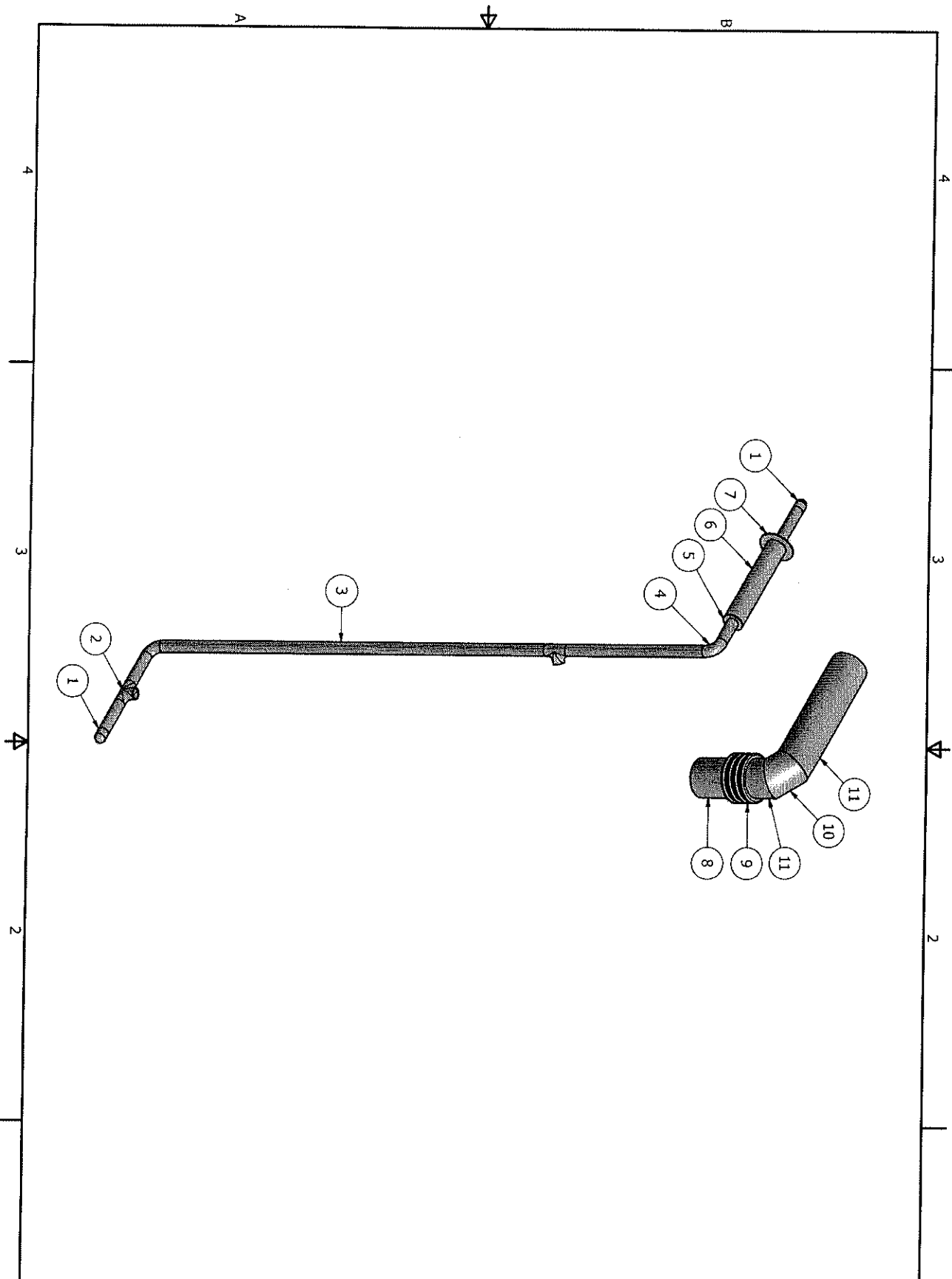



DETAIL A
SCALE 1 : 1

SCALE 1 : 16

REV	STATUS
1	REV
2	-
3	-

NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. 2. ALL DIMENSIONS APPLY AFTER FINISH. 3. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 4. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC. DATE: 11/3/2009 CHKD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:	
8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edenryogenics.com		DATE: 09-0377 DATE: 12/28/2009 SCALE: 1:8		TITLE BC-02128 ASSEMBLY, CRYOGENIC INLET	
SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE	REV
B	BC-02128-5830	1 of 3	-		



NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 11/3/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R .015 MAX.		X.XX ± .010		CHECKED: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		X.XXX ± .005		ENGR: JHM 12/28/2009	
		ANGULAR ± 1/2°		APPROVED:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949		DATE: 12/28/2009	
www.edencyrogenics.com		EDR: 09-0377		ZONE	
SIZE	DRAWING/PART NUMBER	SHEET	REV	DATE	CHANGED BY
B	BC-02128-5830	2 OF 3	-	12/28/2009	EDR
SCALE: 1:12		REVISION DESCRIPTION			

BC-02128
ASSEMBLY, CRYOGENIC INLET

Information Copy

PARTS LIST			
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION
1	2	BC-02128-0061	WELD CAP, 1 NPS X SCH 10
2	2	BC-02128-0062	TEE, 1 NPS X SCH 10
3	A/R	BC-02128-0060	CRYOGENIC INLET, PIPE, 1 NPS X SCH 10
4	2	BC-02128-0063	ELBOW, LR, 1 NPS X SCH 10
5	1	SR-002-036-306	STAND-OFF RING, 1 NPS X 2 NPS X 11 GA.
6	A/R	BC-02128-0067	CRYOGENIC INLET, PIPE, 2 NPS X SCH 10
7	1	BC-02128-0068	STAND-OFF RING, 2 NPS X 4.20 OD X 11 GA
8	1	BC-02128-0070	CRYOGENIC INLET, PIPE, 4 NPS X SCH 40
9	1	BC-02128-0066	CRYOGENIC INLET, BELLOW, 4 NPS
10	1	BC-02128-0069	MITERED ELBOW, PIPE, 4 NPS X SCH 10
11	A/R	BC-02128-0065	CRYOGENIC INLET, PIPE, 4 NPS X SCH 10
12	A/R	BC-02128-0074	INSULATION, PRYOGEL XT

NOTE:

1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. "Ø2" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
3. ALL DIMENSIONS ARE FOR REFERENCE ONLY.
 - 3.1. FINAL DIMENSIONS TO BE VERIFIED AT NEXT ASSEMBLY.
4. FABRICATE PER EDEN SPEC. BC101-50-1001 SECT. 1-9.
5. ALL INNER LINE BUTT WELDS ARE TO BE INSPECTED TO CONFIRM FULL PENETRATION AS FOLLOWS:
 - 5.1 VISUAL EXAMINATION OF ID WHERE POSSIBLE.
 - 5.2 WHERE (5.1) IS NOT POSSIBLE, RANDOM RADIOGRAPHICALLY INSPECT 5% OF ALL INNER LINE BUTT WELDS NOT INCLUDING THOSE EXAMINED VISUALLY. (THIS IS TO BE 5% OF THE ENTIRE JOB, NOT 5 % OF EACH SPOOL). USE SINGLE FILM ONLY.
 6. INSULATION PROVIDED BY CUSTOMER.
 - 6.1 WRAP PIPE WITH TWO 10mm THICK LAYERS OF "PRYOGEL XT".


4

3

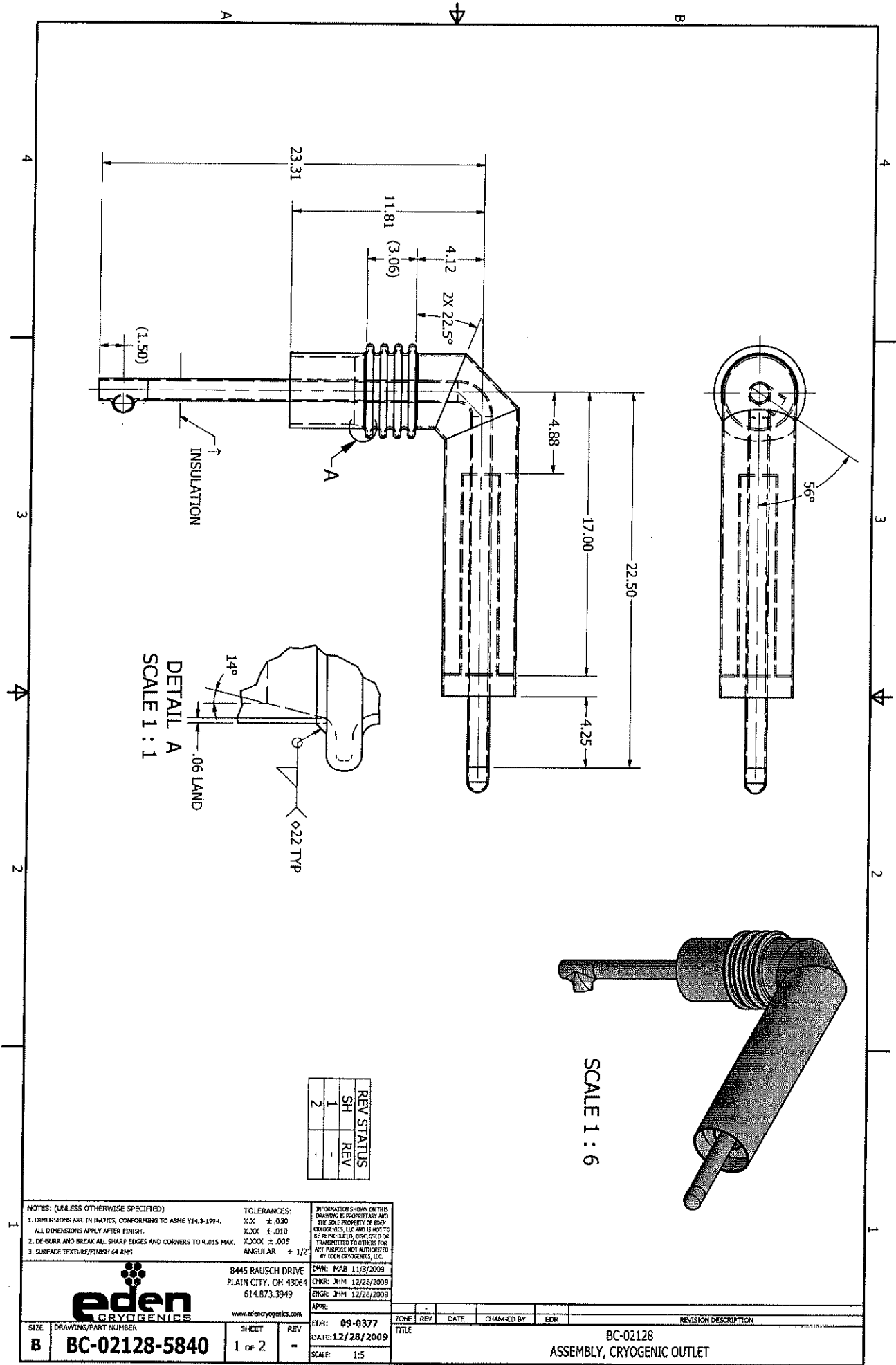
4

2

1

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		OWNER: MAB 11/3/2009	
2. ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHECKER: JHM 12/28/2009	
3. DO NOT BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGINEER: JHM 12/28/2009	
4. SURFACE TEXTURE (RMS) 64 RMS		ANGULAR ± 1/2		APPROVED:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		DATE: 09-0377 DATE: 12/28/2009 SCALE:	
SIZE	DRAWING/PART NUMBER	SHEET	REV	REVISION DESCRIPTION	
B	BC-02128-5830	3 OF 3	-	BC-02128 ASSEMBLY, CRYOGENIC INLET	

Information Copy



REV	STATUS
1	SH
2	REV

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DE BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
3. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
 X.X ± .030
 X.XX ± .010
 X.XXX ± .005
 ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.



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 PLAIN CITY, OH 43064
 614.873.3949

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DATE: 12/28/2009
 DATE: 12/28/2009

APP: 09-0377

SIZE	DRAWING/PART NUMBER	SHEET	REV
B	BC-02128-5840	1 OF 2	-

ZONE	REV	DATE	CHANGED BY	EDK	REVISION DESCRIPTION

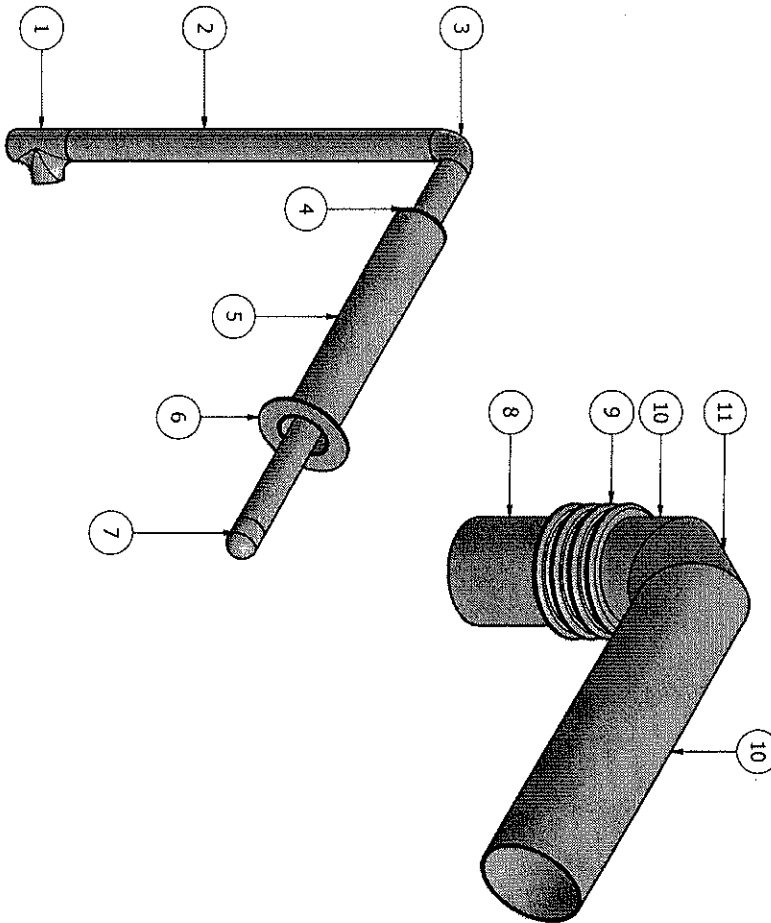
BC-02128
 ASSEMBLY, CRYOGENIC OUTLET

Information Copy

PARTS LIST					
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	1	BC-02128-0062	TEE, 1 NPS X SCH 10		Stainless Steel 304/304L ASME SA403
2	A/R	BC-02128-0071	CRYOGENIC OUTLET, PIPE, 1 NPS X SCH 10	PT-016-010-021	Stainless Steel 304/304L ASME SA312
3	1	BC-02128-0063	ELBOW, LR, 1 NPS X SCH 10		Stainless Steel 304/304L ASME SA403
4	1	SR-002-036-306	STAND-OFF RING, 1 NPS X 2 NPS X 11 GA.		Stainless Steel 304/304L ASTM A240
5	A/R	BC-02128-0072	CRYOGENIC OUTLET, PIPE, 2 NPS X SCH 10	PT-032-010-021	Stainless Steel 304/304L ASME SA312
6	1	BC-02128-0068	STAND-OFF RING, 2 NPS X 4.20 OD X 11 GA		Stainless Steel 304/304L ASTM A240
7	1	BC-02128-0061	WELD CAP, 1 NPS X SCH 10		Stainless Steel 304/304L ASME SA403
8	1	BC-02128-0070	CRYOGENIC INLET, PIPE, 4 NPS X SCH 40	PT-064-040-021	Stainless Steel 304/304L ASME SA312
9	1	BC-02128-0066	CRYOGENIC INLET, BELLOW, 4 NPS		Stainless Steel 304/304L ASME SA321
10	A/R	BC-02128-0073	CRYOGENIC OUTLET, PIPE, 4 NPS X SCH 10	PT-064-010-021	Stainless Steel 304/304L ASME SA312
11	1	BC-02128-0069	MITERED ELBOW, PIPE, 4 NPS X SCH 10	PT-048-010-021	Stainless Steel 304/304L ASME SA312
12	A/R	BC-02128-0074	INSULATION, PRYOGEL XT		

NOTE:

- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
- "Ø22" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
- ALL DIMENSIONS ARE FOR REFERENCE ONLY.
- 3.1. FINAL DIMENSIONS TO BE VERIFIED AT NEXT ASSEMBLY.
- FABRICATE PER EDEN SPEC. BC101-50-1001 SECT. 1-9.
- ALL INNER LINE BUTT WELDS ARE TO BE INSPECTED TO CONFIRM FULL PENETRATION AS FOLLOWS:
 - 5.1 VISUAL EXAMINATION OF ID WHERE POSSIBLE.
 - 5.2 WHERE (5.1) IS NOT POSSIBLE, RANDOM RADIOGRAPHICALLY INSPECT 5% OF ALL INNER LINE BUTT WELDS NOT INCLUDING THOSE EXAMINED VISUALLY, (THIS IS TO BE 5% OF THE ENTIRE JOB, NOT 5 % OF EACH SPOOL). USE SINGLE FILM ONLY.
 6. INSULATION PROVIDED BY CUSTOMER.
 - 6.1 WRAP PIPE WITH TWO 10mm THICK LAYERS OF "PRYOGEL XT".



NOTES: (UNLESS OTHERWISE SPECIFIED)

- DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
- ALL DIMENSIONS APPLY AFTER FINISH.
- BE WORK AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
- SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.

DWG: MAB 11/3/2009
CHKD: JHM 12/28/2009
ENGR: JHM 12/28/2009

APPD:

EDR: 09-0377

DATE: 12/28/2009

SCALE: 1:5



8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.873.3949

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SIZE B DRAWING/PART NUMBER BC-02128-5840

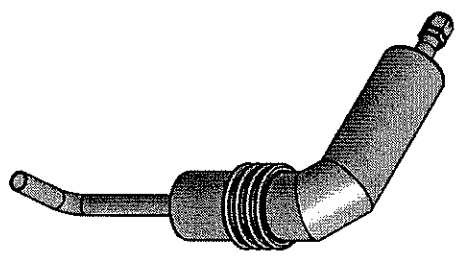
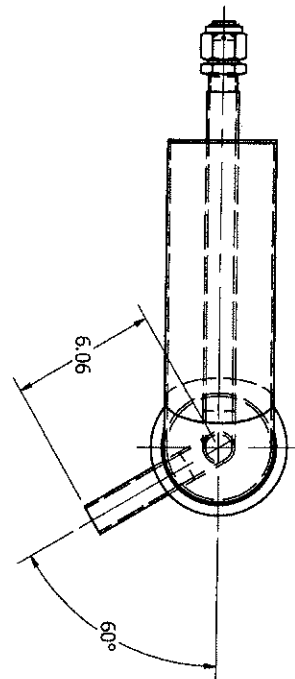
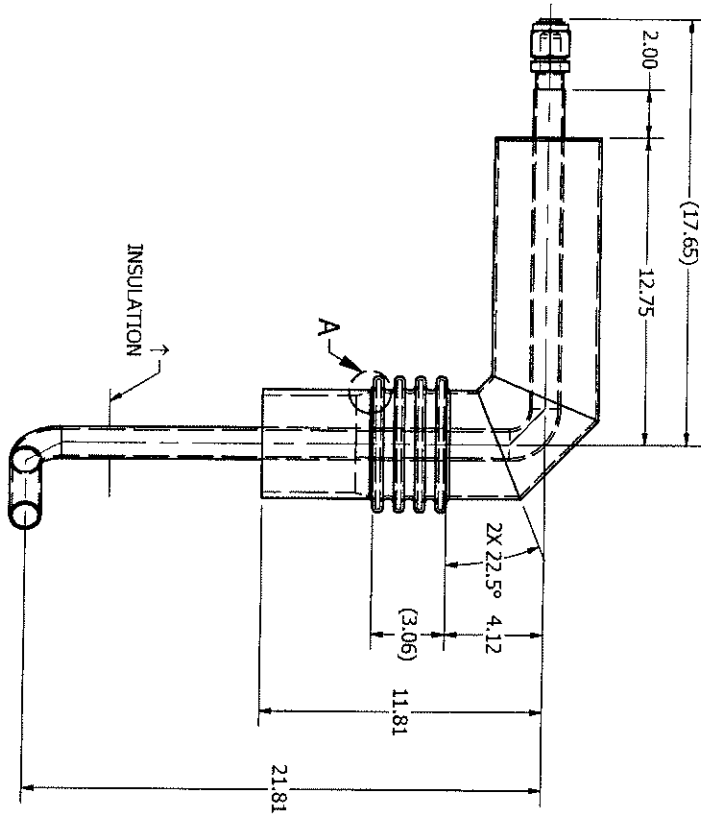
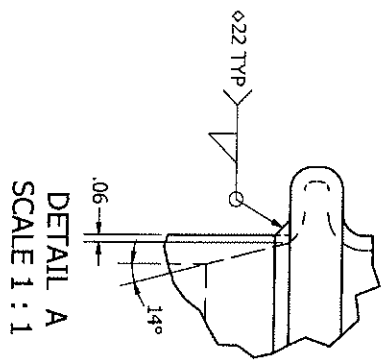
SHEET 2 OF 2

REV -

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION

BC-02128
ASSEMBLY, CRYOGENIC OUTLET

Information Copy



SCALE 1 : 8

REV STATUS	
SH	REV
1	-
2	-

NOTES: (UNLESS OTHERWISE SPECIFIED)

- DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
- ALL DIMENSIONS APPLY AFTER FINISH.
- DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
- SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:

X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, COPIED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.

DWN: MAB 11/3/2009
CHK: JHM 12/28/2009
ENGR: JHM 12/28/2009

APPL: 09-0377
DATE: 12/28/2009
SCALE: 1:4

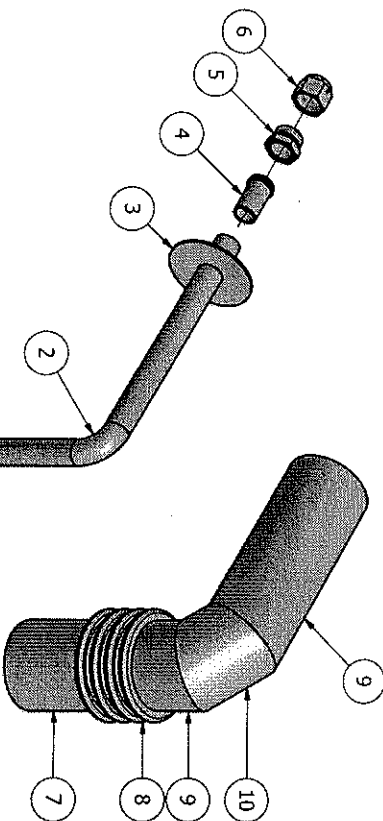
8445 RAUSCH DRIVE
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eden
CRYOGENICS

SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION
B	BC-02128-5850	1 of 2	-						BC-02128 ASSEMBLY, REGENERATION GAS OUTLET

Information Copy

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	A/R	BC-02128-0081	PIPE, 1 NPS X SCH 10
2		BC-02128-0063	ELBOW, LR, 1 NPS X SCH 10
3	1	SR-002-064-306	STAND-OFF RING, 1 NPS X 4 NPS X 11 GA
4	1	BC-02128-0083	WELD GLAND, 1 OD
5	1	BC-02128-0084	VCR, MALE NUT, 1 OD
6	1	BC-02128-0085	VCR, CAP, 1 OD
7	1	BC-02128-0070	CRYOGENIC INLET, PIPE, 4 NPS X SCH 40
8	1	BC-02128-0066	CRYOGENIC INLET, BELLOW, 4 NPS
9	A/R	BC-02128-0082	PIPE, 4 NPS X SCH 10
10	1	BC-02128-0069	MITERED ELBOW, PIPE, 4 NPS X SCH 10
11	A/R	BC-02128-0074	INSULATION, PRYOGEL XT



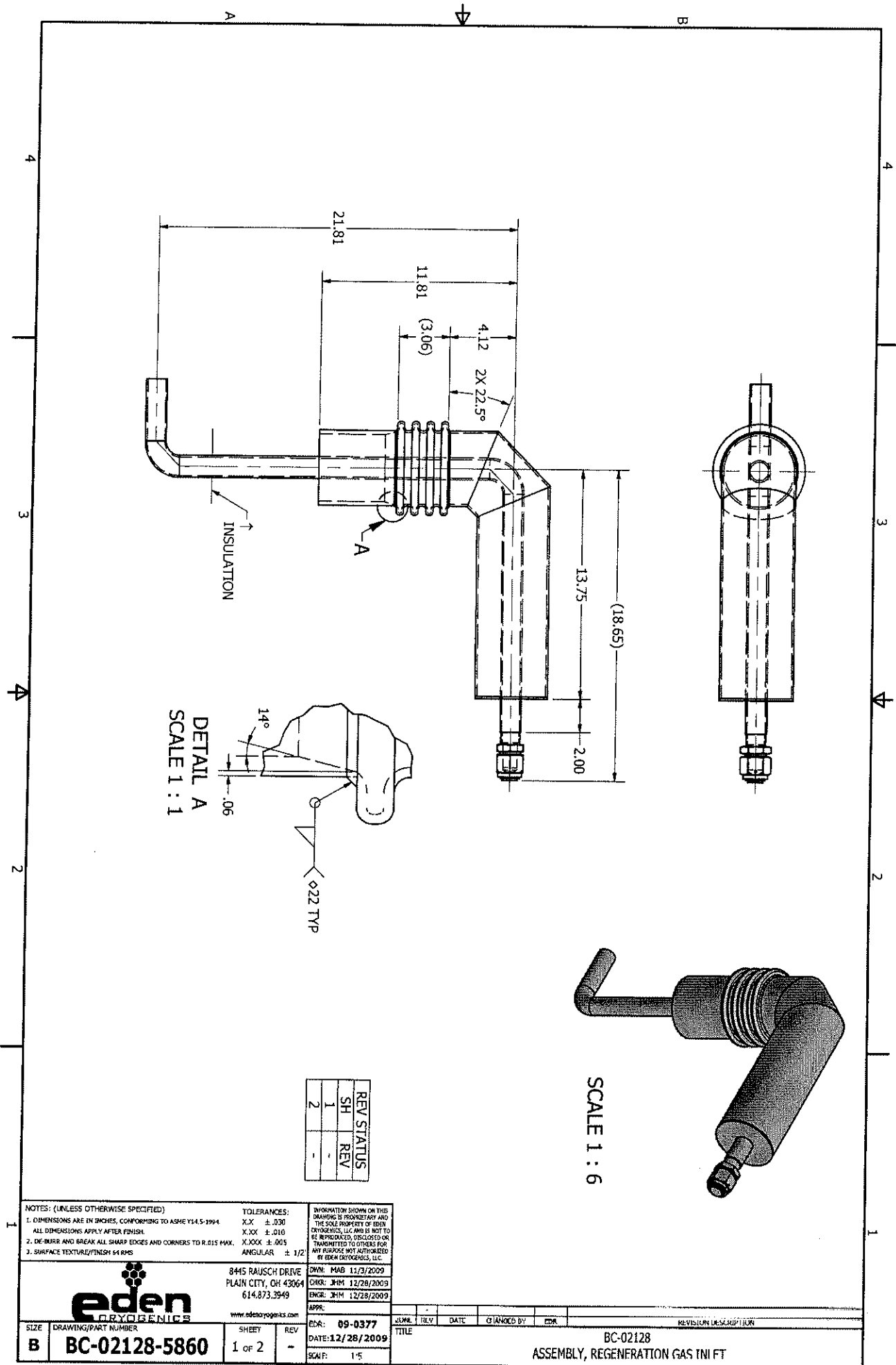
NOTE:

- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
- "ø.22" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
- ALL DIMENSIONS ARE FOR REFERENCE ONLY.
- 3.1. FINAL DIMENSIONS TO BE VERIFIED AT NEXT ASSEMBLY.
- FABRICATE PER EDEN SPEC. BC101-50-1001 SECT. 1-9.
- ALL INNER LINE BUTT WELDS ARE TO BE INSPECTED TO CONFIRM FULL PENETRATION AS FOLLOWS:
 - 5.1 VISUAL EXAMINATION OF ID WHERE POSSIBLE.
 - 5.2 WHERE (5.1) IS NOT POSSIBLE, RANDOM RADIOGRAPHICALLY INSPECT 5% OF ALL INNER LINE BUTT WELDS NOT INCLUDING THOSE EXAMINED VISUALLY, (THIS IS TO BE 5% OF THE ENTIRE JOB, NOT 5 % OF EACH SPOOL). USE SINGLE FILM ONLY.
- INSULATION PROVIDED BY CUSTOMER.
- 6.1 WRAP PIPE WITH TWO 10mm THICK LAYERS OF "PRYOGEL XT".

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSES NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWN: MAB 11/3/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHKR: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPR:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyro.com		DATE: 12/28/2009 SCALE: 1:6	
SIZE: B	DRAWING/PART NUMBER: BC-02128-5850	SHEET: 2 of 2	REV: -	ZONE: REV: DATE: CHANGED BY: EDR:	

BC-02128
ASSEMBLY, REGENERATION GAS OUTLET

Information Copy



REV	STATUS
1	REV
2	-

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DEBURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
3. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.



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DWN: MAB 11/3/2009
CHK: JHM 12/28/2009
ENG: JHM 12/28/2009

APP: JHM 12/28/2009

DATE: 12/28/2009

SCALE: 1 : 6

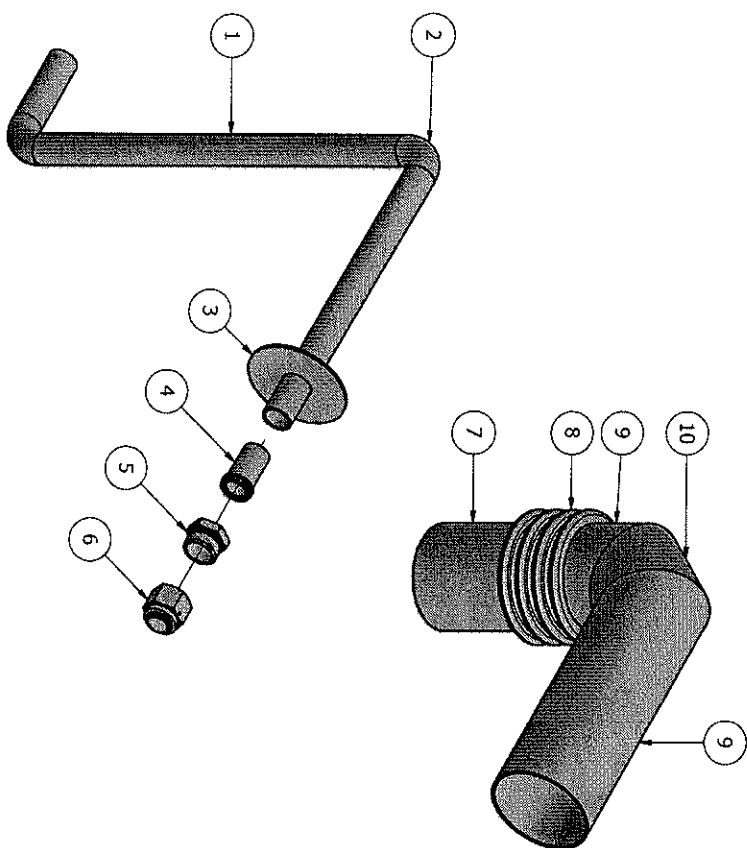
SIZE	DRAWING/PART NUMBER	SHEET	REV
B	BC-02128-5860	1 of 2	-


DATE	CHANGED BY	EDN	REVISION DESCRIPTION
12/28/2009	JHM		BC-02128
			ASSEMBLY, REGENERATION GAS INLET

Information Copy

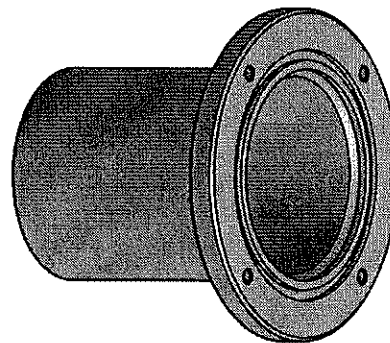
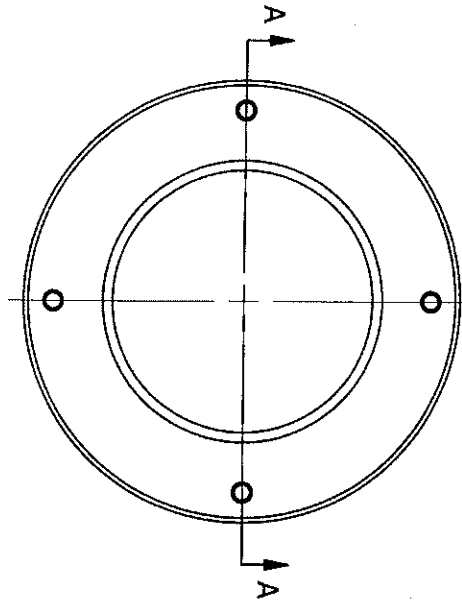
PARTS LIST					
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	A/R	BC-02128-0091	PIPE, 1 NPS X SCH 10	PI-016-010-021	Stainless Steel 304/304L ASME SA312
2		BC-02128-0063	ELBOW, LR, 1 NPS X SCH 10		Stainless Steel 304/304L ASME SA403
3	1	SR-002-064-306	STAND-OFF RING, 1 NPS X 4 NPS X 11 GA		Stainless Steel 304/304L ASTM A240
4	1	BC-02128-0083	WELD GLAND, 1 OD		Stainless Steel 304/304L
5	1	BC-02128-0084	VCR, MALE NUT, 1 OD		Stainless Steel 316/316L
6	1	BC-02128-0085	VCR, CAP, 1 OD		Stainless Steel 316/316L
7	1	BC-02128-0070	CRYOGENIC INLET, PIPE, 4 NPS X SCH 40	PI-064-040-021	Stainless Steel 304/304L ASME SA312
8	1	BC-02128-0066	CRYOGENIC INLET, BELLOW, 4 NPS		Stainless Steel 304/304L ASME SA321
9	A/R	BC-02128-0092	PIPE, 4 NPS X SCH 10	PI-016-010-021	Stainless Steel 304/304L ASME SA312
10	1	BC-02128-0069	MITERED ELBOW, PIPE, 4 NPS X SCH 10	PI-048-010-021	Stainless Steel 304/304L ASME SA312
11	A/R	BC-02128-0074	INSULATION, PRYOGEL XT		

- NOTE:**
- BREAK ALL SHARP EDGES AND CORNERS TO R.005.
 - "Ø22" WELD PER EDEN SPEC BC101-001-022, LATEST REV.
 - ALL DIMENSIONS ARE FOR REFERENCE ONLY.
 - 3.1. FINAL DIMENSIONS TO BE VERIFIED AT NEXT ASSEMBLY.
 - FABRICATE PER EDEN SPEC. BC101-50-1001 SECT. 1-9.
 - ALL INNER LINE BUTT WELDS ARE TO BE INSPECTED TO CONFIRM FULL PENETRATION AS FOLLOWS:
 - 5.1 VISUAL EXAMINATION OF ID WHERE POSSIBLE.
 - 5.2 WHERE (5.1) IS NOT POSSIBLE, RANDOM RADIOGRAPHICALLY INSPECT 5% OF ALL INNER LINE BUTT WELDS NOT INCLUDING THOSE EXAMINED VISUALLY, (THIS IS TO BE 5% OF THE ENTIRE JOB, NOT 5 % OF EACH SPOOL). USE SINGLE FILM ONLY.
 - INSULATION PROVIDED BY CUSTOMER.
 - 6.1 WRAP PIPE WITH TWO 10mm THICK LAYERS OF "PRYOGEL XT".



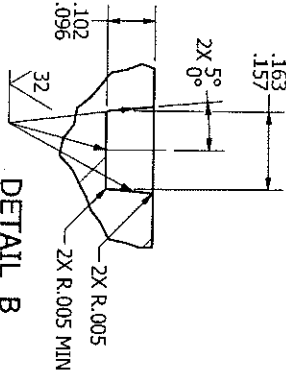
NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 11/3/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHECKED: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGINEER: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPROVED:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:5	
SIZE	DRAWING/PART NUMBER	SHEET	REV	ZONE REV DATE CHANGED BY EDR	
B	BC-02128-5860	2 OF 2	-	REVISION DESCRIPTION	
				BC-02128 ASSEMBLY, REGENERATION GAS INLET	

Information Copy



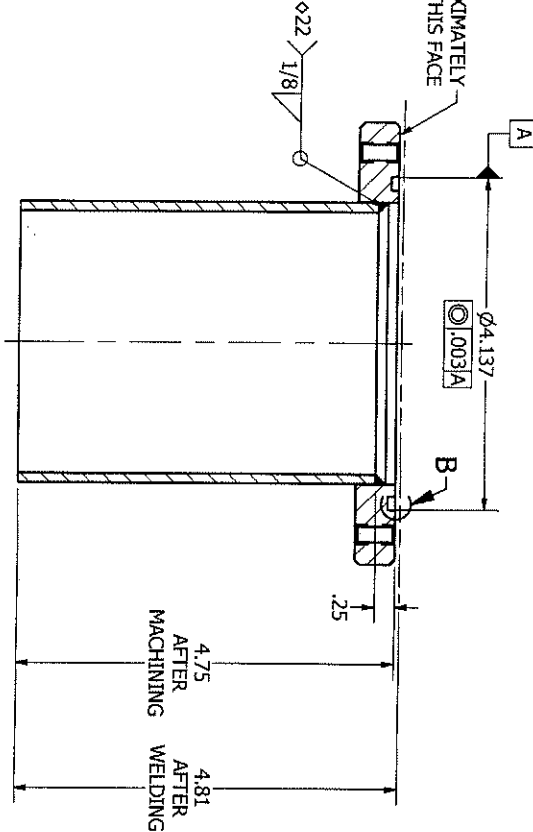
SCALE 1 : 2

DETAIL B
SCALE 4 : 1



REMOVE APPROXIMATELY
.06 FROM THIS FACE

SECTION A-A
SCALE 2 : 3



NOTE:
1. BREAK ALL SHARP EDGES AND
CORNERS TO R.005.
2. ".022" WELD PER EDEN SPEC
BC101-001-022, LATEST REV.

REV STATUS	
SH	REV
1	-
2	-

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.0.05.
3. SURFACE TEXTURE/FINISH: 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

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OWN: MAS 12/23/2009
CHK: JHM 12/28/2009
ENGR: JHM 12/28/2009

APPR: EDR: 09-0377
DATE: 12/28/2009

SCALE: 2:3

SIZE
B

DRAWING/PART NUMBER
BC-02128-5875

SHEET
1 OF 2

REV
-

ZONE
TITLE

REV

DATE

CHANGED BY

EDR

REVISION DESCRIPTION

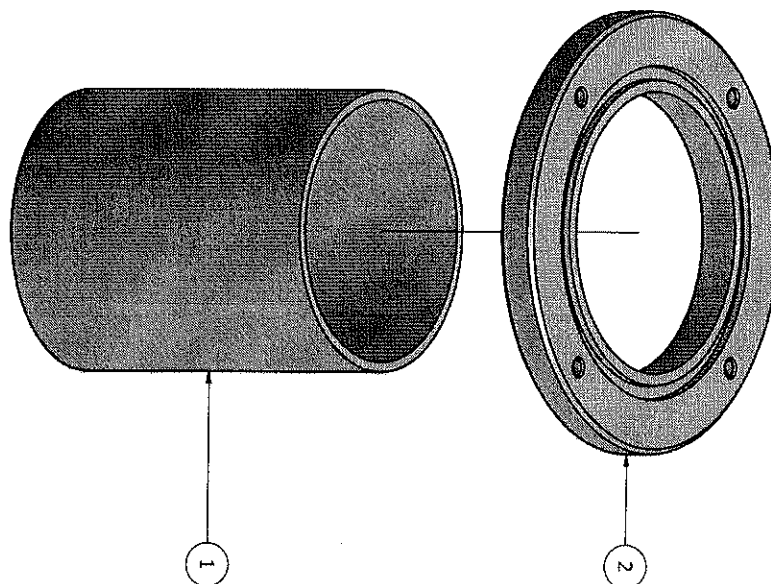
BC-02128

WELDMENT, PARALLEL PLATE RELIEF, BOTTOM PLATE

Information Conv

v10.18.12. 123 / 424

PARTS LIST			
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION
1	1	BC-02128-0101	PARALLEL PLATE RELIEF, PIPE, 3 NPS X SCH 10 X 4 1/2 LG
2	1	BC-02128-0102	PARALLEL PLATE RELIEF, BOTTOM PLATE
STOCK NUMBER			MATERIAL
PT-048-010-021			Stainless Steel 304/304L ASTM A312
			Stainless Steel 304/304L ASTM A240



NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DIMENSIONS APPLY AFTER FINISH.
3. SURFACE TEXTURE/FINISH: 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.



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DWN: MAB 12/23/2009
CHKD: JHM 12/28/2009
ENGR: JHM 12/28/2009
APPD:

EDR: 09-0377

DATE: 12/28/2009

SCALE: 2:3

SIZE B DRAWING/PART NUMBER BC-02128-5875

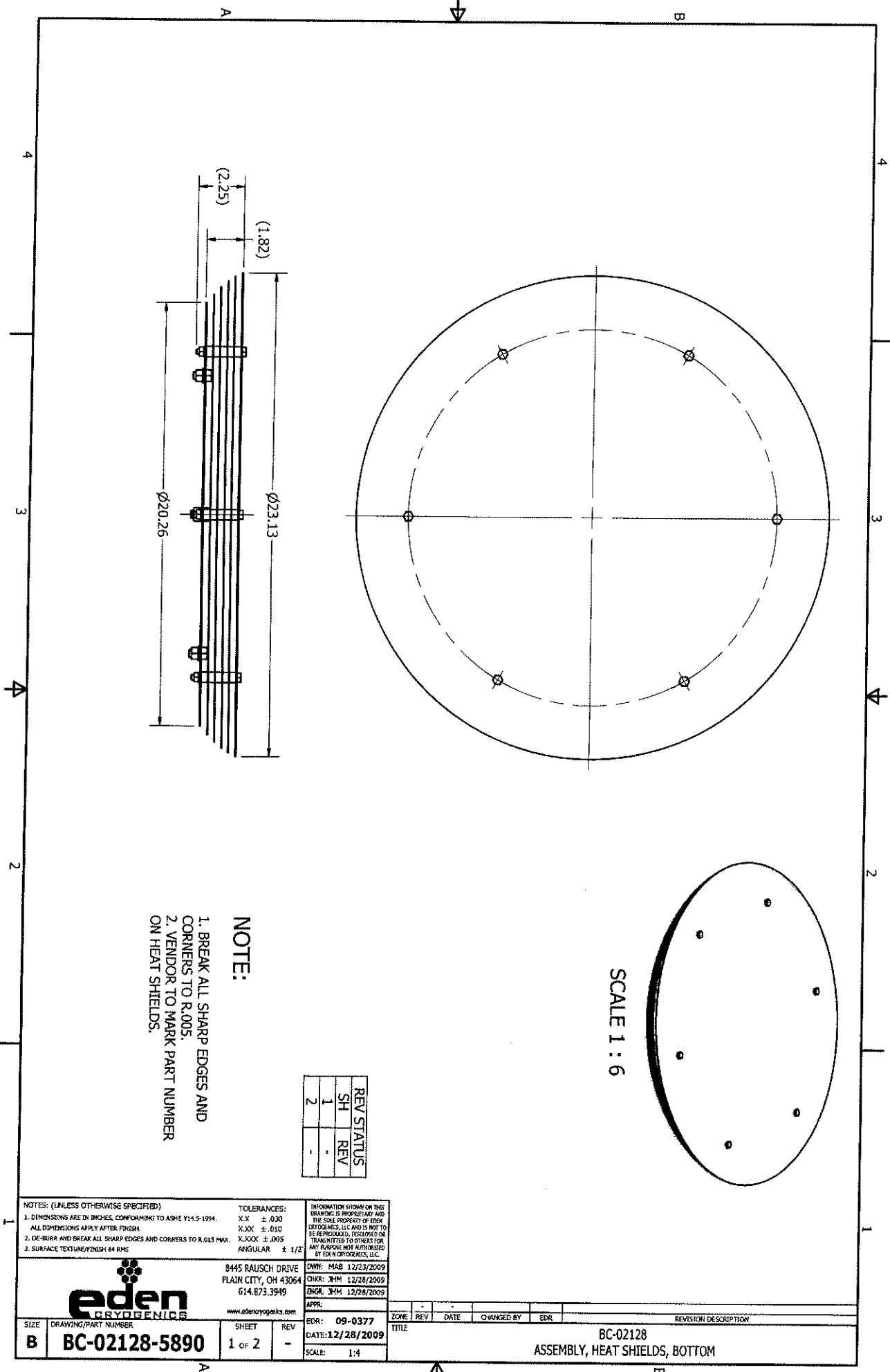
SHEET 2 OF 2

REV

TITLE

BC-02128
WELDMENT, PARALLEL PLATE RELIEF, BOTTOM PLATE

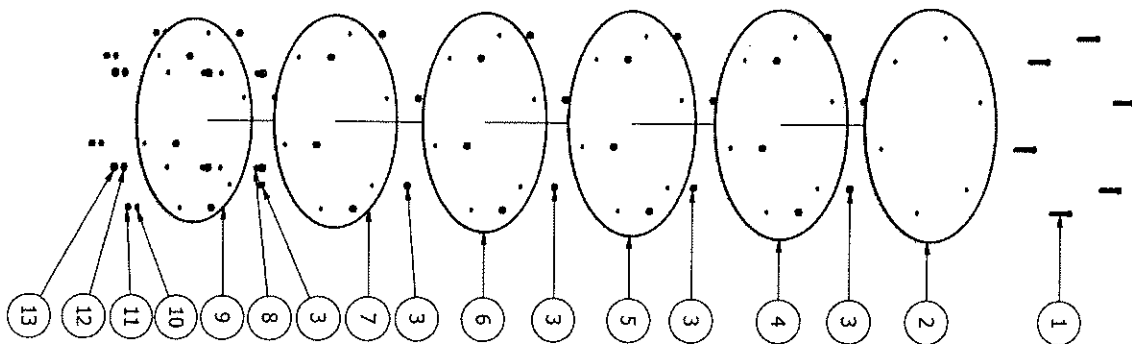
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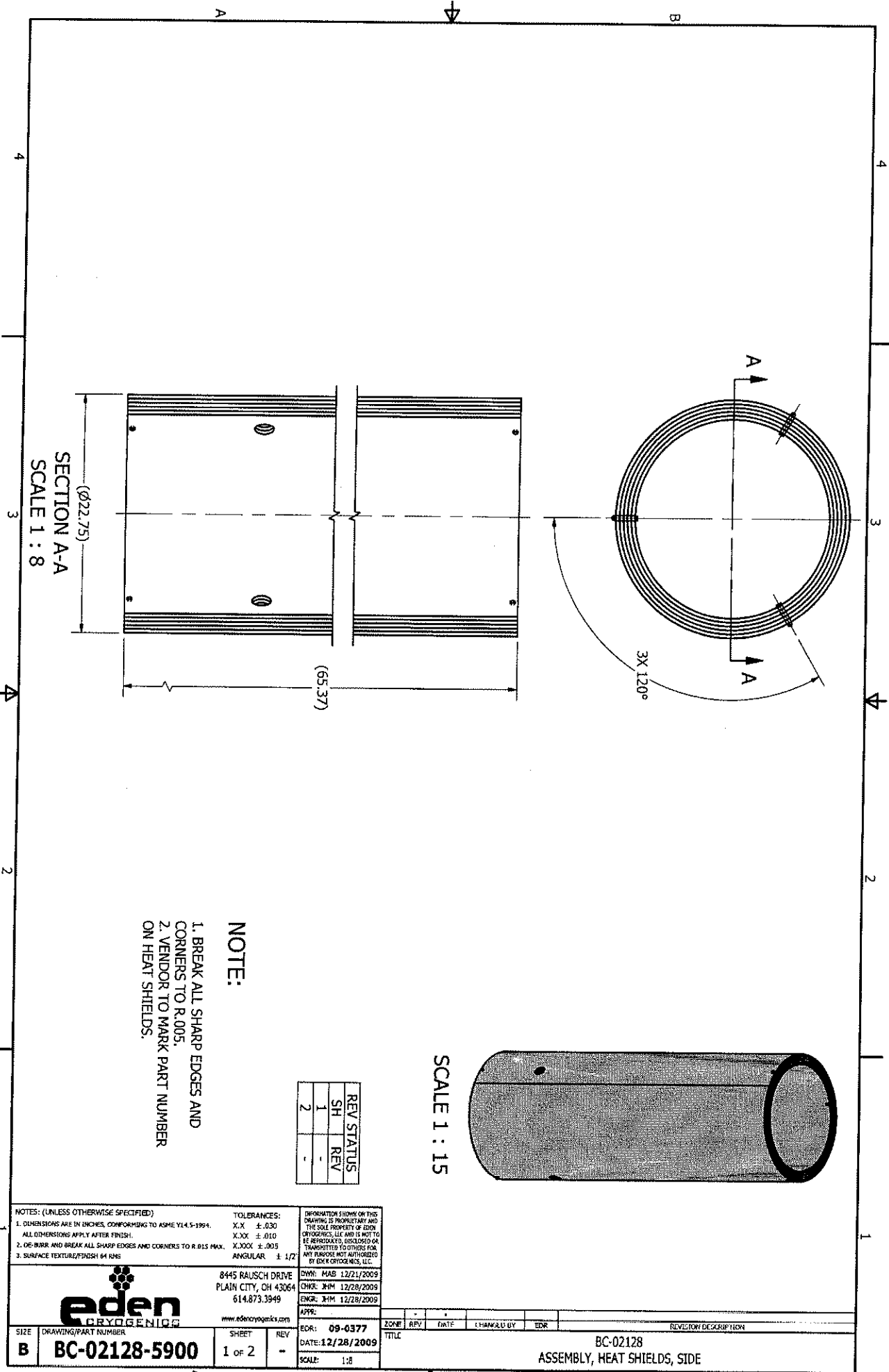
REV	STATUS
1	SH
2	REV

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DRAWN: MAB 12/23/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHECK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGL: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH: 64 RMS		ANGULAR ± 1/2°		APPR:	
EDEN CRYOGENICS		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edenryogenics.com		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:4	
SIZE	DRAWING/PART NUMBER	SHEET	REV	TITLE	
B	BC-02128-5890	1 OF 2	-	BC-02128 ASSEMBLY, HEAT SHIELDS, BOTTOM	

PARTS LIST					
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION	STOCK NUMBER	MATERIAL
1	6	FA-004-112-167	HEX BOLT - INCH 1/4-20 UNC - 2.25		Stainless Steel 18-8
2	1	BC-02128-0021	BOTTOM HEAT SHIELD		Aluminum-6061 ASTM B209
3	30	BC-02128-0122	SPACER	92320A663	Stainless Steel 18-8
4	1	BC-02128-0022	BOTTOM HEAT SHIELD		Aluminum-6061 ASTM B209
5	1	BC-02128-0023	BOTTOM HEAT SHIELD		Aluminum-6061 ASTM B209
6	1	BC-02128-0024	BOTTOM HEAT SHIELD		Aluminum-6061 ASTM B209
7	1	BC-02128-0025	BOTTOM HEAT SHIELD		Aluminum-6061 ASTM B209
8	4	FA-006-112-105	HEX BOLT - INCH 3/8-16 UNC - 5/8		Stainless Steel 18-8
9	1	BC-02128-0026	BOTTOM HEAT SHIELD		Aluminum-6061 ASTM B209
10	6	FA-004-812-030	SPRING LOCK WASHER, 3/8		Stainless Steel 18-8
11	6	FA-004-812-006	HEX NUT - INCH 1/4 - 20 UNC		Stainless Steel 304/304L ASTM A194 GR 8
12	4	FA-006-812-030	SPRING LOCK WASHER, 3/8		Stainless Steel 18-8
13	4	FA-006-812-006	HEX NUT - INCH 3/8 - 16 UNC		Stainless Steel 304/304L ASTM A194 GR 8



NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ±.030 X.XX ±.010 X.XXX ±.005 ANGULAR ± 1/2°	INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC. DWN: MAB 12/23/2009 CHKD: JHM 12/28/2009 ENGR: JHM 12/28/2009 APPR:
 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyogenics.com		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:12	
SIZE: B DRAWING/PART NUMBER: BC-02128-5890 SHEET: 2 OF 2 REV:	TITLE: BC-02128 ASSEMBLY, HEAT SHIELDS, BOTTOM		



SECTION A-A
SCALE 1 : 8

NOTE:
1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELDS.

REV	STATUS
1	REV
2	-

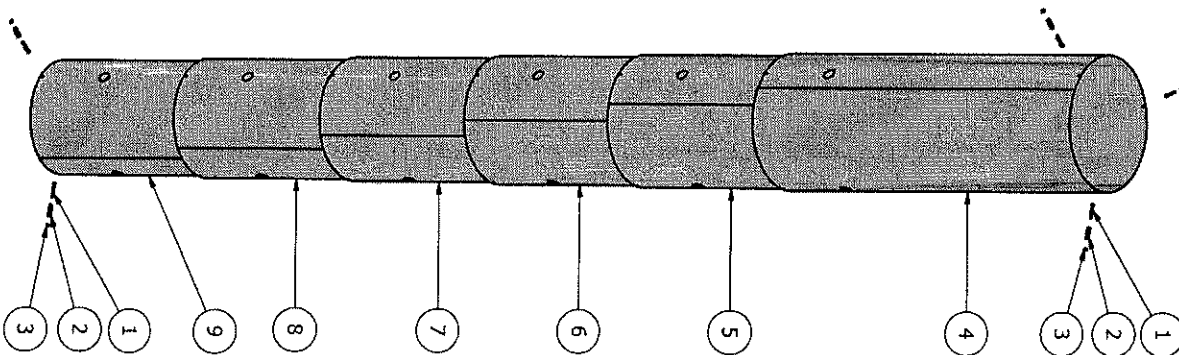
SCALE 1 : 15

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWN: MAB 12/21/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHKD: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPR:	
EDEN CRYOGENICS		8445 RAUSCH DRIVE		EOR: 09-0377	
www.edencyro.com		PLAIN CITY, OH 43064		DATE: 12/28/2009	
SHEET		REV		SCALE: 1:8	
1 OF 2		-			

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION

BC-02128
ASSEMBLY, HEAT SHIELDS, SIDE

PARTS LIST			
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION
1	6	FA-004-112-167	HEX BOLT - INCH 1/4-20 UNC - 2.25
2	30	BC-02128-0122	SPACER
3	6	FA-004-812-006	HEX NUT - INCH 1/4 - 20 UNC
4	1	BC-02128-0031	SIDE HEAT SHIELD
5	1	BC-02128-0032	SIDE HEAT SHIELD
6	1	BC-02128-0033	SIDE HEAT SHIELD
7	1	BC-02128-0034	SIDE HEAT SHIELD
8	1	BC-02128-0035	SIDE HEAT SHIELD
9	1	BC-02128-0036	SIDE HEAT SHIELD



NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
3. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
 X.X .±.030
 X.XX .±.010
 X.XXX .±.005
 ANGULAR .±.1/2°

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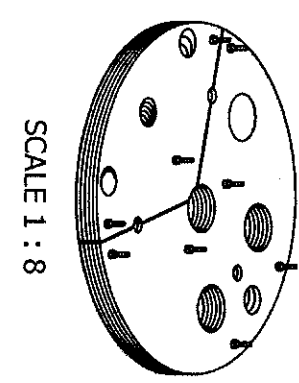
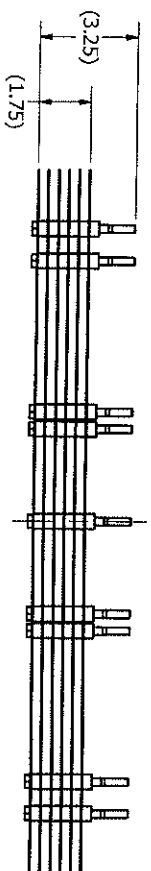
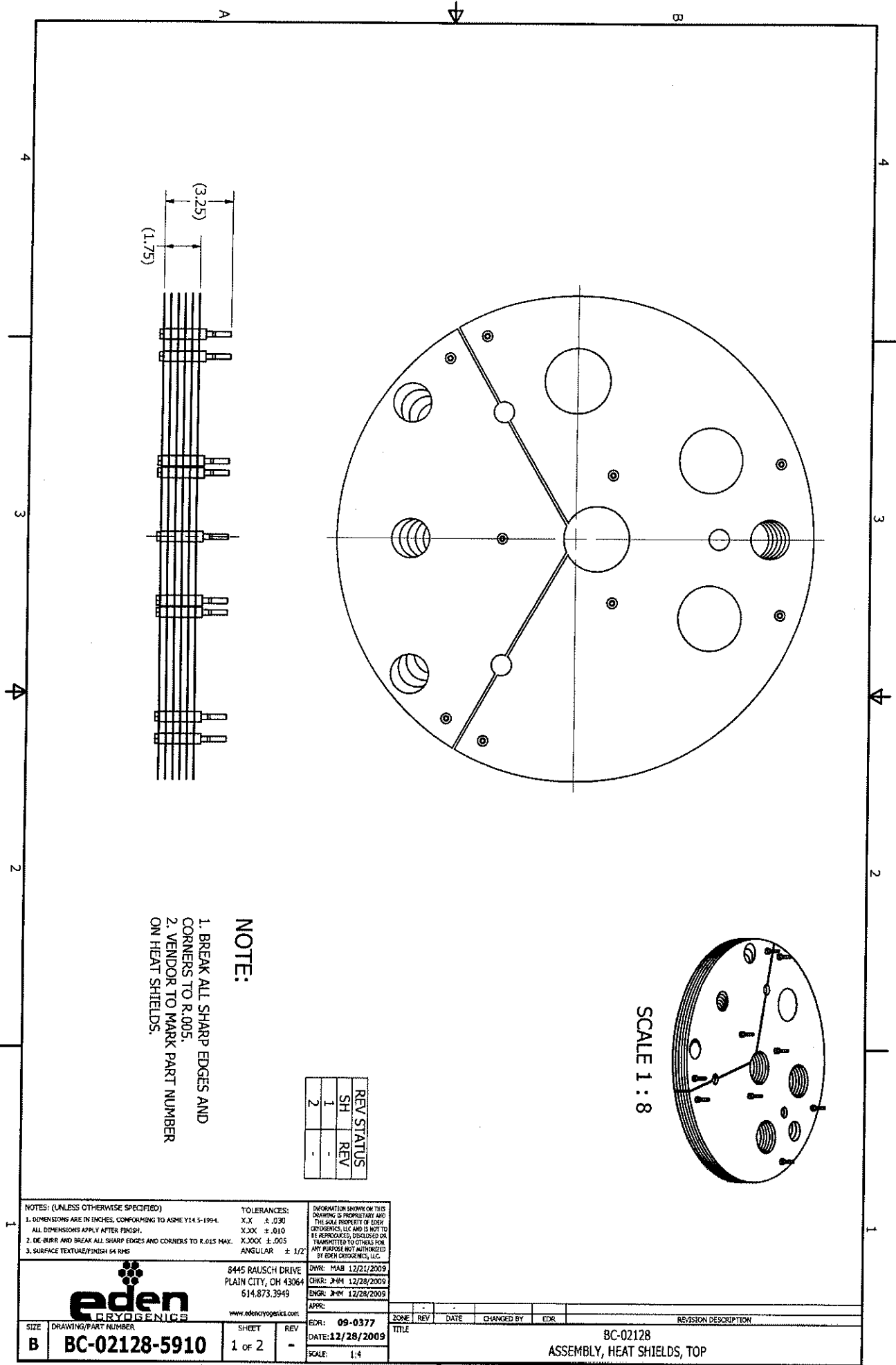
www.edencyrogenics.com

DATE: 12/21/2009
 CHKD: JHM 12/28/2009
 ENGR: JHM 12/28/2009
 APPR:
 EDR: 09-0377
 DATE: 12/28/2009
 SCALE: 1:20

SIZE	DRAWING/PART NUMBER	SHEET	REV
B	BC-02128-5900	2 OF 2	

TITLE
 BC-02128
 ASSEMBLY, HEAT SHIELDS, SIDE


Information Copy



NOTE:

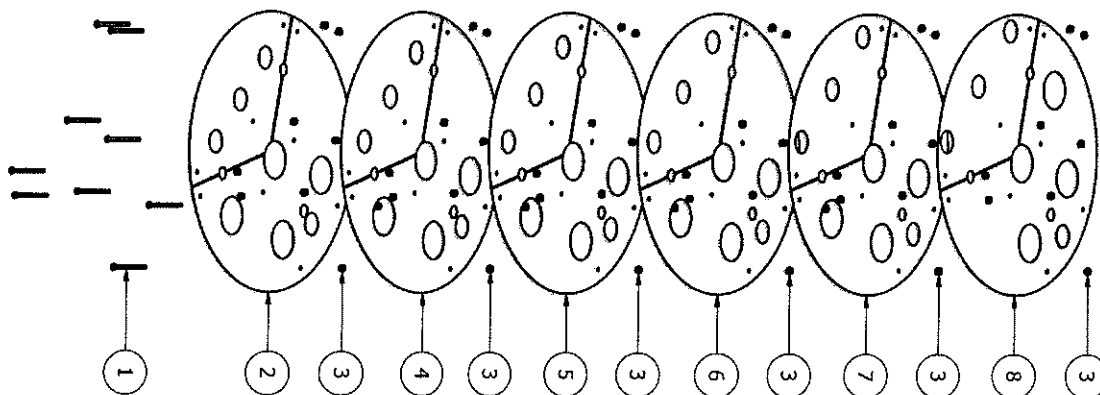
1. BREAK ALL SHARP EDGES AND CORNERS TO R.005.
2. VENDOR TO MARK PART NUMBER ON HEAT SHIELDS.

REV	STATUS
1	REV
2	-

NOTES: (UNLESS OTHERWISE SPECIFIED)		TOLERANCES:		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.		X.X ± .030		DWG: MAB 12/21/2009	
ALL DIMENSIONS APPLY AFTER FINISH.		X.XX ± .010		CHK: JHM 12/28/2009	
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.		X.XXX ± .005		ENGR: JHM 12/28/2009	
3. SURFACE TEXTURE/FINISH 64 RMS		ANGULAR ± 1/2		APPR:	
		8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edencyrogenics.com		EDR: 09-0377	
SIZE	DRAWING/PART NUMBER	SHEET	REV	DATE	TITLE
B	BC-02128-5910	1 OF 2	-	12/28/2009	BC-02128 ASSEMBLY, HEAT SHIELDS, TOP
				SCALE: 1:4	

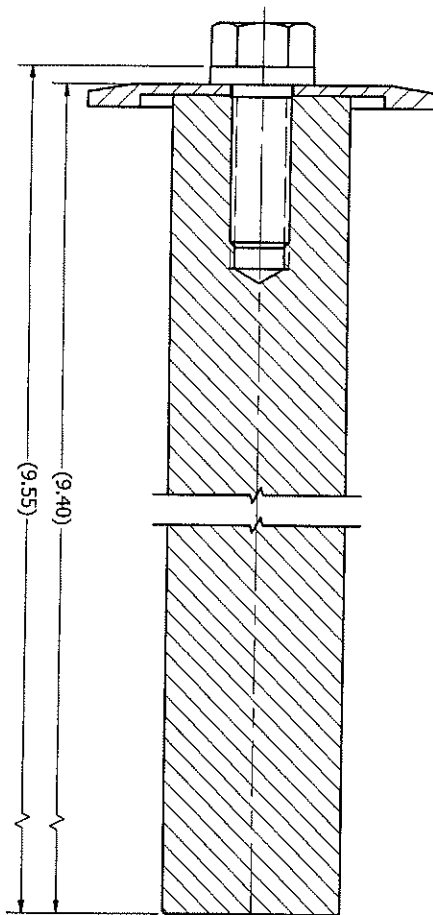
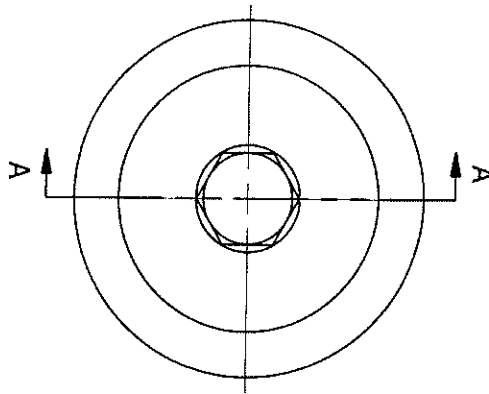
Information Copy

PARTS LIST			
ITEM	ITEM QTY	PART NUMBER	DESCRIPTION
1	9	FA-004-112-171	HEX BOLT - INCH, 1/4-20 UNC X 3 1/4 LG
2	1	BC-02128-0015	TOP HEAT SHIELD
3	54	BC-02128-0122	SPACER
4	1	BC-02128-0014	TOP HEAT SHIELD
5	1	BC-02128-0013	TOP HEAT SHIELD
6	1	BC-02128-0012	TOP HEAT SHIELD
7	1	BC-02128-0011	TOP HEAT SHIELD
8	1	BC-02128-0010	TOP HEAT SHIELD



NOTES: (UNLESS OTHERWISE SPECIFIED) 1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994. ALL DIMENSIONS APPLY AFTER FINISH. 2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX. 3. SURFACE TEXTURE/FINISH 64 RMS		TOLERANCES: X.X ± .030 X.XX ± .010 X.XXX ± .005 ANGULAR ± 1/2°		INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF EDEN CRYOGENICS, LLC AND IS NOT TO BE REPRODUCED, DISCLOSED OR TRANSMITTED TO OTHERS FOR ANY PURPOSE NOT AUTHORIZED BY EDEN CRYOGENICS, LLC.	
eden CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 614.873.3949 www.edenryogenics.com		DWN: MAB 12/21/2009 CHKD: JHM 12/28/2009 ENGR: NRI 12/28/2009 APPR:		EDR: 09-0377 DATE: 12/28/2009 SCALE: 1:10	
SIZE B	DRAWING/PART NUMBER BC-02128-5910	SHEET 2 OF 2	REV	TITLE BC-02128 ASSEMBLY, HEAT SHIELDS, TOP	

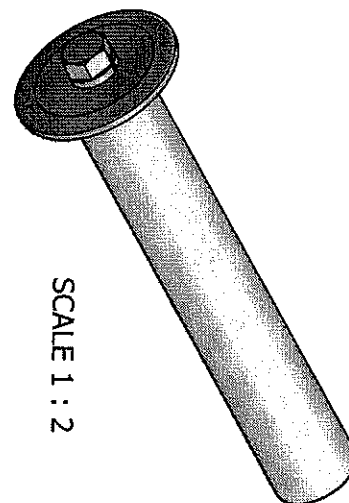
Information Copy



SECTION A-A
SCALE 1 : 1

NOTE:
BREAK ALL SHARP EDGES AND
CORNERS TO R.005.

REV STATUS	
SH	REV
1	-
2	-



SCALE 1 : 2

NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
3. SURFACE TEXTURE/FINISH 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

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8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.873.3949

www.edencyrogenics.com

DATE: 12/23/2009
CHK: JHM 12/28/2009
ENGR: JHM 12/28/2009

APP: 09-0377

SIZE B DRAWING/PART NUMBER
BC-02128-5920

SHEET 1 of 2

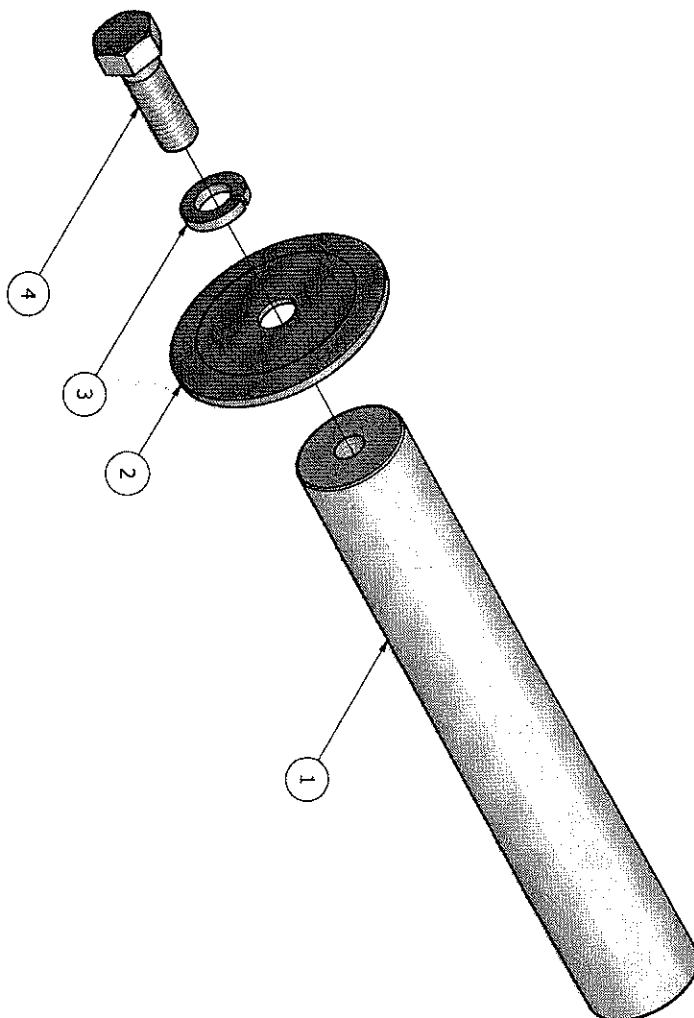
REV -
DATE: 12/28/2009
SCALE: 1:1

ZONE	REV	DATE	CHANGED BY	EDR	REVISION DESCRIPTION

BC-02128
SHIPPING PLUG

Information Copy

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	BC-02128-0113	SHIPPING SUPPORT PLUG
2	1	BC-02128-0114	FLANGE, BLANK, NW50, MODIFIED, MDC VACUUM PRODUCTS
3	1	FA-008-812-031	SPRING LOCK WASHER, 1/2
4	1	FA-008-112-312	HEX BOLT - INCH 1/2-13 UNC - 1 1/2
		STOCK NUMBER	MATERIAL
		712003	Aluminum-6061
			Stainless Steel 304/304L
			Stainless Steel 18-8



NOTES: (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONS ARE IN INCHES, CONFORMING TO ASME Y14.5-1994.
2. DE-BURR AND BREAK ALL SHARP EDGES AND CORNERS TO R.015 MAX.
3. SURFACE TEXTURE/FINISH: 64 RMS

TOLERANCES:
X.X ± .030
X.XX ± .010
X.XXX ± .005
ANGULAR ± 1/2°

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8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
614.673.3949

www.edencyogenics.com

DATE: MAR 12/23/2009
CHKD: JHM 12/28/2009
ENGR: JHM 12/29/2009

APP: _____

EDR: 09-0377

DATE: 12/28/2009

SCALE: 2:3

SIZE B DRAWING/PART NUMBER BC-02128-5920

SHEET 2 of 2

REV _____

TITLE BC-02128 SHIPPING PLUG

Information Copy

PAGE NO.	HEAT NUMBER	PO NUMBER	DESCRIPTION	AREA
CRYO INLET				
1	4130-0607	BC-1134	3" NPS PIPE	RELIEF PLATE
2	8A1219	BC-2972	4" NPS PIPE X SCH 40	CRYO INLET
3	391025	BC-3276	4" NPS PIPE X SCH 10	CRYO INLET
4	4110-0807	BC-2674	1" NPS PIPE	CRYO INLET
5	4110-0810	BC-2674	1" NPS PIPE	CRYO INLET
6	041126	BC-3312	2" NPS PIPE	CRYO INLET
7	I-827466	BC-2387	4" BELLOWS	CRYO INLET
8	4TK4	BC-3350	STAND-OFF RING	CRYO INLET
9	8BCC1	BC-3276	1" ELOW	CRYO INLET
10	096178V21	BC-3276	1" TEE	CRYO INLET
11	T74877	BC-2845	1" CAP	CRYO INLET
12	S22320	BC-3779	1" CAP	CRYO INLET

GAS OUTLET				
2	8A1219	BC-2972	4" NPS PIPE X SCH 40	GAS OUTLET
3	391025	BC-3276	4" NPS PIPE X SCH 10	GAS OUTLET
13	829979	BC-3276	1" NPS PIPE	GAS OUTLET
7	I-827466	BC-2387	4" BELLOWS	GAS OUTLET
8	4TK4	BC-3350	STAND-OFF RING	GAS OUTLET
4	4110-0807	BC-2674	1" NPS PIPE	GAS OUTLET
9	8BCC1	BC-3276	1" ELOW	GAS OUTLET

CRYO OUTLET				
2	8A1219	BC-2972	4" NPS PIPE X SCH 40	CRYO OUTLET
3	391025	BC-3276	4" NPS PIPE X SCH 10	CRYO OUTLET
13	829979	BC-3276	1" NPS PIPE	CRYO OUTLET
6	041126	BC-3312	2" NPS PIPE X SCH 10	CRYO OUTLET
7	I-827466	BC-2387	4" BELLOWS	CRYO OUTLET
8	4TK4	BC-3350	STAND-OFF RING	CRYO OUTLET
15	T36378	BC-3276	1" NPS PIPE	CRYO OUTLET
9	8BCC1	BC-3276	1" ELOW	CRYO OUTLET
14	O181	BC-3276	1" CAP	CRYO OUTLET
10	096178V21	BC-3276	1" TEE	CRYO OUTLET
16	364604	BC-3767	1" TEE	CRYO OUTLET

GAS OUTLET				
2	8A1219	BC-2972	4" NPS PIPE X SCH 40	GAS OUTLET
3	391025	BC-3276	4" NPS PIPE X SCH 10	GAS OUTLET
13	829979	BC-3276	1" NPS PIPE	GAS OUTLET

7	I-827466	BC-2387	4" BELLOWS	GAS OUTLET
8	4TK4	BC-3350	STAND-OFF RING	GAS OUTLET
9	8BCC1	BC-3276	1" EBLOW	GAS OUTLET

OUTER VESSEL

17	ZT0081	BC-3276	24" NPS RFSO FLANGE	FLANGE
18	BB070102	BC-3276	24" NPS WELD CAP	WELD CAP
19	BB070021	BC-3276	24" NPS WELD CAP	WELD CAP
20	YX0806-410	BC-3276	2" OD TUBE	EXT TUBE
21	4HK1	BC-3176	3" X 3" ANGLE	VESSEL LEGS
22	231105	BC-3175	1/2" PLATE	FEET
23	YTB71241	BC-3276	24" NPS BLIND FLANGE	TOP FLANGE
24	5EX7	BC-3420	6"X6" PLATE	LIFT PLATES
25	482863	BC-3276	24" NPS PIPE	SHELL

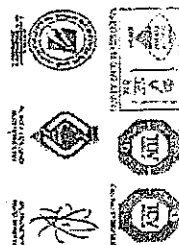
INNER VESSEL

22	231105	BC-3175	PLATE STOCK	HANGERS
14	O181	BC-3276	1" WELD CAP	INLET / OUTLET
26	139308	BC-3276	3" NPS WELD CAP	FILL PORT
27	BB070055	BC-3276	12" NPS WELD CAP	INNER VESSEL
13	829979	BC-3276	1" PIPE	INLET / OUTLET
28	391025	BC-3276	3" NPS PIPE	FILL PORT
29	280463	BC-3276	12" NPS PIPE	INNER VESSEL
30	1.4404	BC-3279	FILTER	FILTER
31	3C730	BC-3283	THERMOWELL	THERMOWELLS
32	156654/252208	BC-3427	BAR	FILTER SUPPORTS



Kanzen Teisu Sdn Bhd

Company No. 198092-V
P.O. Box 7272, Telok Perak, Perak
Selatan 31, 40700 Shah Alam, Selangor (Jarak Pekan, Malaysia)
Tel: (603) 5542 1400 Fax: (603) 5541 9777
http://www.kanzen-teisu.com e-mail: info@kanzen-teisu.com



MILL TEST REPORT

EN 10204 3.1

CERTIFICATE NO :

9128356 (1)

DATE : 17/07/2006

CONTRACT NO :

9106546

SHIPPER :

KANZEN TEISU SDN BHD

CUSTOMER :

MEAL BRASS

(CONSUMER)
PRODUCT SPECIFICATION

WELDED AUSTENITIC STAINLESS STEEL
PRES ASTM A312/ASME SA312-04B

SIZE	QTY	TOTAL LENGTH	WEIGHT KGS	HEAT NO	TENSILE TEST			HARDNESS TEST (HRB)	HYDRO-STATIC TEST (MPa)	TUB. HYDRO. TEST	CORROSION ASTM A262 PRACTICE E	CHEMICAL COMPOSITION (%)							
					YS	T	EL					C	SI	MN	P	S	NI	CR	MO
TP304/304L X 1-1/2" X SCH40S	25	-	479	4115-0607	331	685	53	84	12.4	PASSED	PASSED	3.5	100	200	45	30	800	1800	-
PRODUCT CODE: 15724												1.8	44	127	34	2	801	1836	-
TP304/304L X 2" X SCH40S	75	-	1817	4120-0607	369	688	51	88	9.7	PASSED	PASSED	1.8	44	127	34	2	801	1836	-
PRODUCT CODE: 15752												1.6	42	139	29	2	802	1818	-
TP304/304L X 2-1/2" X SCH40S	25	-	810	4125-0507	321	692	51	83	9.0	PASSED	PASSED	1.6	42	139	29	2	802	1818	-
PRODUCT CODE: 15740												1.8	50	126	29	1	801	1804	-
TP304/304L X 3" X SCH40S	30	-	1196	4130-0607	344	658	53	88	7.6	PASSED	PASSED	1.4	46	133	36	5	800	1823	-
PRODUCT CODE: 15748												2.1	47	132	25	2	803	1815	-
TP304/304L X 4" X SCH40S	30	-	1547	4140-0606	322	661	54	88	5.5	PASSED	PASSED	3.0	49	176	29	1	810	1820	-
PRODUCT CODE: 15764												1.5	45	137	35	2	802	1805	-
TP304/304L X 6" X SCH40S	10	-	852	4160-0607	339	651	53	87	4.5	PASSED	PASSED	2.1	47	132	25	2	803	1815	-
PRODUCT CODE: 15736												1.5	45	137	35	2	802	1805	-
TP304/304L X 3/8" X SCH40S	15	-	78	4402-0506	284	606	57	80	17.2	PASSED	PASSED	2.1	47	132	25	2	803	1815	-
PRODUCT CODE: 15106												2.1	47	132	25	2	803	1815	-
TP304/304L X 1/2" X SCH40S	50	-	390	4405-0607	347	652	52	86	17.2	PASSED	PASSED	2.1	47	132	25	2	803	1815	-
PRODUCT CODE: 15108												2.1	47	132	25	2	803	1815	-
TP304/304L X 1" X SCH40S	75	-	1156	4410-0607	339	653	53	87	17.2	PASSED	PASSED	2.1	47	132	25	2	803	1815	-
PRODUCT CODE: 15116												2.1	47	132	25	2	803	1815	-
TP304/304L X 1-1/4" X SCH40S	15	-	313	4412-0607	277	617	53	81	17.2	PASSED	PASSED	1.8	51	126	27	4	804	1833	-
PRODUCT CODE: 15120																			
TP304/304L X 1-1/2" X SCH40S	74	-	1845	4415-0511	359	678	52	87	15.9	PASSED	PASSED								
PRODUCT CODE: 15126																			

HEAT TREATMENT : 1050 DEGREE CELSIUS OVERHEATED IN WATER

NOTE : YS = YIELD STRENGTH
T = TENSILE STRENGTH
EL = ELONGATION IN 50MM
HRB = HARDNESS





MILL TEST CERTIFICATE

Shanghai Want Industry Co., Ltd. (EN10204.3.1)

ROBERT JAMES SALES, INC.
THESE TEST REPORTS APPLY TO

证书号: EN10204:2004

证书号: MTC-WANT-WG828-28-2-06

Certificate: EN10204:2004

Certificate No: MTC-WANT-WG828-28-2-06

客户/Client:

SILBO INDUSTRIES, INC.

订单号/Order No.:

98004

品名/Article:

无缝钢管/Seamless stainless pipe SA312

技术条件/Specification:

ASTMA376-02A/SA376

材料/Material:

ASTMA312/ASME SA312-304/304L

加工/Workmanship:

冷拔/Cold drawing

交货状态/Delivery Conditions: Annealed, pickled

产品交货范围/Extent of material delivery

标识/Marking:

Manufacture's mark: WANT

Standard:

ASTMA312/ASME SA312

Specifications

ITEM NO. Dimension Size

Grade Material:

ITEM NO. 304/304L

Heat Number:

8A1219

LC NO: SNI 850187

钢级	规格	炉批号	炉号	数量	英尺 (ft)	重量(kg)
Grade	Dimension	Lot NO.	Heat No.	Pcs	Quantity(ft)	Weight(kg)
304/304L	4" SCH40S	HD081001-03	8A1219	18	355.28	1743

试验结果/Test Results: 标准要求已符合, 见如下表格/The requirements are fulfilled as listed in Annex.

A 化学分析/Chemical analysis:

炉号/Heat No.	C%	Mn%	Si%	S%	P%	Cr%	Ni%	Mo%
ASTM A312/ASME	≤	≤	≤	≤	≤	18.0-	8.0-	/
SA312-304/304L	0.035	2.00	1.00	0.030	0.045	20.0	11.0	/
8A1219	0.029	1.28	0.37	0.004	0.041	18.20	8.05	/

B 机械性能/Mechanical Properties/tensile test:

试样号	试验温度	屈服强度	抗拉强度	延伸%	硬度	冲击试验
Specimen	Test Temp	Yield Strength	Tensile Strength	Elongation	Hardness	Charpy Impact
Nr./No.		Mpa	Mpa	%	HRB	
ASTM A312/ASME	25	≥205	≥515	≥35	≤90	-
SA312-304/304L						
19	8A1219	260	565	58	78	-

C 无损探伤, 尺寸检查及水压试验/Hydrostatic Test, NDT and Dimension check:

试验/Testing	结果/Result	试验/Testing	结果/Results
尺寸公差/Tolerance check	OK	水压试验/Hydrostatic pressure test	N/A
外观检查/Visual check	OK	PMI 测试/PMI Test	PASSED
ET Test	PASSED	晶间腐蚀/IGC to ASTM A262 "E"	PASSED
扩口测试/Flaring Test	PASSED	压扁测试/Flattening Test	PASSED

D 备注/Remarks:

MATERIAL IS CERTIFIED ISO 9001:2000

MATERIAL IS NACE MR0175 COMPLIANT

MATERIAL IS FREE OF MERCURY CONTAMINATION

MATERIAL IS PED 97/23/EC CERTIFIED

MATERIAL IS EN10204-3.1 COMPLIANT

MATERIAL IS NACE MR0103-2003 COMPLIANT

1. 热处理 / annealing (at 1050°C, not less than 15.min) and quenched

We hereby certify that the product described herein has been manufactured in accordance with the specifications concerned and also with the purchaser's requirements and that the test results shown herein are correct

NO WELD REPAIR



FELKER BROTHERS CORPORATION
22 NORTH CHESTNUT AVE
MARSHFIELD, WI USA 54449
(800) 828-2304

CERTIFIED MATERIAL REPORT

Heat# 391025 ✓

CERTIFIED DATE: 10/14/2009

PRODUCT

Part Description	PIPE A312-304L 4 SCH10S		
Primary Specification	ASTM A312 08		
Grade	TP304/TP304L		
Other Specifications	ASME SA312 01	MIL-P-24691 / 3	NACE MRO 103
	NACE MRO 175		

CHEMICAL COMPOSITION

Carbon	.023
Chromium	18.030
Copper	.390
Manganese	1.350
Molybdenum	.240
Nickel	8.110
Nitrogen	.040
Phosphorus	.026
Silicon	.450
Sulfur	.013

MECHANICAL PROPERTIES

Elongation	2IN	63.0
Hardness	RB	79
Tensile	PSI	91100
Yield	PSI	35000

MANUFACTURER STEPS

Anneal Temperature	F	1900
Bend / Reverse Bend Test		Pass
Corrosion Test A262 Practice E		Pass
Dimensional / Visual		Pass
Eddy Current - Weld - E426		Pass
Eddy Current - Full Body - E426		Pass
Etching Test - Weld		Pass
Pickling / Passivation ASTM A380		Yes

COMMENTS

Country of melt is UNITED STATES OF AMERICA
Manufactured in USA
TP304/TP304L Dual Cert, Welded
Felker Brothers does not use mercury in the production nor the testing of its products

CERTIFICATION

It is certified that all figures are correct as contained in the records of the company.
We certify that these products conform to specifications listed above.
ISO 9001 Certified
DIN 50049 3.1/EN 10204 3.1
FAR BAA Complies
DFARS BAA Complies
FAR TAA Complies

Scott Martinek
Quality Manager

3

S E N O I R I A N B E R H A D

Kanzen Tetsu Sdn Bhd

Company No. 1908971V
P.O. Box 7272, Lot 4 Persiaran Perusahaan
Seksyen 23, 40708 Shah Alam, Selangor Darul Ehsan, Malaysia.
Tel: (603) 5542 1400 Fax: (603) 5541 9777
http://www.kanzen-tetsu.com e-mail: info@kanzen-tetsu.com



MILL TEST REPORT

EN 10204 3.1

CERTIFICATE NO : 9133379 (1) DATE : 14/11/2008
CONTRACT NO : 9107154
SHIPPER : KANZEN TETSU SDN BHD
ORDER NO. : 0603KAM
CUSTOMER : MERITI BRASS
PRODUCT : WELDED AUSTENITIC STAINLESS STEEL
SPECIFICATION : PIPES ASTM A312/ASME SA312H-08

SIZE	QTY PCS	TOTAL LENGTH	WEIGHT KGS	HEAT NO	TENSILE TEST			HARD- NESS TEST (HRB)	HYDRO- STATIC TEST MPa	FLAC- TING TEST	CORROSION ASTM A262 PRACTICE E	CHEMICAL COMPOSITION (%)							
					Y.S. N/mm ²	T.S. N/mm ²	EL.%					C	SI	Mn	P	S	NI	Cr	MO
TP304/304L X 1" X SCH40S PRODUCT NO. P5016	641	-	9683	4410-0811	337	640	48	89	17.2	PASSED	PASSED	3.5	100	200	45	30	800	1800	-
TP304/304L X 1" X SCH40S PRODUCT NO. P5016	259	-	3993	4410-0810	268	607	53	82	17.2	PASSED	PASSED	2.6	46	146	36	4	802	1872	-
TP304/304L X 1-1/4" X SCH40S PRODUCT NO. P5020	34	-	710	4412-0810	276	627	55	82	17.2	PASSED	PASSED	1.9	40	139	28	4	800	1808	-
TP304/304L X 1-1/4" X SCH40S PRODUCT NO. P5020	86	-	1796	4412-0808	275	613	55	82	17.2	PASSED	PASSED	2.1	42	133	28	3	803	1817	-
TP304/304L X 1-1/2" X SCH40S PRODUCT NO. P5024	222	-	5534	4415-0810	284	622	52	82	15.9	PASSED	PASSED	2.3	36	141	27	10	801	1826	-
TP304/304L X 1-1/2" X SCH40S PRODUCT NO. P5024	178	-	4437	4415-0811	278	627	50	79	15.9	PASSED	PASSED	2.2	37	150	24	2	812	1823	-
TP304/304L X 3" X SCH40S PRODUCT NO. P5046	100	-	6958	4430-0810	314	607	52	83	13.1	PASSED	PASSED	2.4	49	136	37	9	806	1816	-
TP304/304L X 4" X SCH40S PRODUCT NO. P5064	25	-	2476	4440-0811	286	602	54	83	11.0	PASSED	PASSED	2.0	45	143	42	8	806	1827	-
TP304/304L X 1" X SCH10S PRODUCT NO. 15716	156	-	2011	4110-0807	327	662	51	84	17.2	PASSED	PASSED	1.5	49	143	34	3	808	1818	-
TP304/304L X 1" X SCH10S PRODUCT NO. 15716	94	-	1213	4110-0810	327	662	51	84	17.2	PASSED	PASSED	2.1	45	134	30	1	801	1808	-
TP304/304L X 2" X SCH10S PRODUCT NO. 15732	97	-	2350	4120-0807	304	646	51	85	9.7	PASSED	PASSED	2.1	45	134	30	1	801	1808	-
												2.8	34	150	32	6	821	1843	-

HEAT TREATMENT : 1050 DEGREE CELSIUS QUENCHED IN WATER

NOTE : Y.S. = YIELD STRENGTH
T.S. = TENSILE STRENGTH
EL. = ELONGATION IN 50mm
for +DI, min, %

QA DEPARTMENT



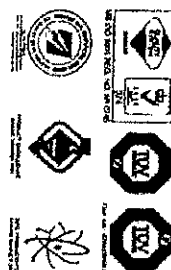
A subsidiary of FACB Industri Berhad

KT/DOX/QA-22 R4

S E N O I A R I A N S E R N A D

Kanzen Ietsu Sdn Bhd

Company No. 190897-W
P.O. Box 7272, Lot 4 Persiaran Perusahaan
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MILL TEST REPORT

EN 10204 3.1

CERTIFICATE NO : 9132379 (1) DATE : 11/11/2008

CONTRACT NO : 9107154
SHIPPER : KANZEN IETSU SDN BHD

ORDER NO. : 0603KAM
CUSTOMER : HERTI BRASS

PRODUCT : WELDED AUSTENITIC STAINLESS STEEL
SPECIFICATION : PIPES ASTM A312/ASME SA312M-08

SIZE	QTY PCS	TOTAL LENGTH	WEIGHT KGS	HEAT NO	TENSILE TEST			HARD- NESS TEST (HRB)	HYDRO- STATIC TEST MPa	FLAT TENSILE TEST	CORROSION TEST ASTM A262 PRACTICE E	CHEMICAL COMPOSITION (%)							
					VS. N	T.S. N	EL. %					C	Si	Mn	P	S	NI	Cr	Mo
TP304/304L X 1" X SCH40S PRODUCT NO. P5016	661	-	9883	4410-0811	337	640	48	89	17.2	PASSED	PASSED	3.5	100	200	45	30	800	1800	-
TP304/304L X 1" X SCH40S PRODUCT NO. P5016	259	-	3993	4410-0810	268	607	53	82	17.2	PASSED	PASSED	2.6	46	146	36	4	802	1822	-
TP304/304L X 1-1/4" X SCH40S PRODUCT NO. P5020	34	-	710	4412-0810	278	627	53	82	17.2	PASSED	PASSED	1.9	40	139	28	4	808	1808	-
TP304/304L X 1-1/4" X SCH40S PRODUCT NO. P5020	86	-	1796	4412-0808	275	613	55	82	17.2	PASSED	PASSED	2.1	42	133	28	3	803	1817	-
TP304/304L X 1-1/2" X SCH40S PRODUCT NO. P5024	222	-	5534	4415-0810	284	622	52	82	15.9	PASSED	PASSED	2.3	36	141	27	10	801	1826	-
TP304/304L X 1-1/2" X SCH40S PRODUCT NO. P5024	178	-	4437	4415-0811	278	627	50	79	15.9	PASSED	PASSED	2.2	37	150	24	2	812	1823	-
TP304/304L X 3" X SCH40S PRODUCT NO. P5046	100	-	6958	4430-0810	314	607	52	83	13.1	PASSED	PASSED	2.4	49	136	37	9	806	1816	-
TP304/304L X 4" X SCH40S PRODUCT NO. P5064	25	-	2476	4440-0811	288	602	54	83	11.0	PASSED	PASSED	2.0	45	143	42	8	806	1827	-
TP304/304L X 1" X SCH10S PRODUCT NO. P5716	156	-	2011	4110-0807	327	662	51	84	17.2	PASSED	PASSED	1.5	49	143	34	3	808	1818	-
TP304/304L X 1" X SCH10S PRODUCT NO. P5716	94	-	1213	4110-0810	327	662	51	84	17.2	PASSED	PASSED	2.1	45	134	30	1	801	1808	-
TP304/304L X 2" X SCH10S PRODUCT NO. P5732	97	-	2350	4120-0807	304	646	51	85	9.7	PASSED	PASSED	2.1	45	134	30	1	801	1808	-
												2.8	34	150	32	6	821	1843	-

HEAT TREATMENT : 1050 DEGREE CELSIUS QUENCHED IN WATER

NOTE : Y.S. = YIELD STRENGTH
T.S. = TENSILE STRENGTH
EL. = ELONGATION IN 50mm
for 4D, min. %

Q/DEPARTMENT



K1/DX/X/DA/22 R4

MANUFACTURER

Schoeller-Bleckmann Pipe & Tube Inc
5430 Brystone Drive
Houston TX77041

SHIP TO

HOUSTON TX
4732 DARIEN
HOUSTON TX77028

SHIP FROM

Schoeller-Bleckmann
Edelstahlrohr GmbH
Rohrstrasse 1
Ternitz FF2630

MANUFACTURING PLANT

Schoeller-Bleckmann
Edelstahlrohr GmbH
Rohrstrasse 1
Ternitz FF2630

HEAT # 041126

MCJUNKIN PO NUMBER S012102450

PART # 6661-0535 LINE # 000001

SHIPPED 09/10/28

VENDOR ORDER NUMBER 8502820

- SPECIFICATIONS *-*

SEE BELOW

--*-* NOTES *-*-*-*

The material had been furnished in accordance
to the requirements.

WE CERTIFY THAT THIS MATERIAL HAS BEEN MANUFACTURED
AND EXAMINED IN ACCORDANCE WITH ALL REQUIREMENTS OF
THE SPECIFICATION AND ORDER CONFIRMATION AND THAT THE
RESULTS OF ALL EXAMINATIONS ARE ACCEPTABLE.

--* DESCRIPTION *-*-*

TP304/L 2" NBXSCH 10S

SEAML. STAINL. STEEL TUBES/PIPES

S GRADE A600, TP304/TP304L,
FINISH CFD = COLD FINISHED, HEAT-TREATED, PICKLED,
TECHN. COND. ACC.

ASTM A312/A312M-06, ASTM A376/A376M-06,
ASME SECT.II PART.A SA312/SA312M-2007 ED.,
ASME SECT.II PART.A SA376/SA376M-2007 ED.,
NACE MR0175/ISO 15156-3:2003, NACE MR0103-2005
CORR. TEST TO MIL-P-24691/3 (ASTM A262 PCT.E)

, &SPACE&

TOLERANCES ACC.

ASTM A999/A999M-04A,

ASME SECT.II PART.A SA530/SA530M-2007 ED.

RANDOM LENGTH

6.100 MM - 7.300 MM,

PLAIN ENDS

, &SPACE&

INTERGR. CORR. TEST ACC. TO ASTM A262 PRACT.E: SATISFACTORY
POSITIVE MATERIAL IDENTIFICATION TEST ON EACH TUBE/PIPE
BY "X-RAY-FLUORESCENCE-ANALYZER": SATISFACTORY

FLATTENING TEST: SATISFACTORY

SOLUTION ANNEALED AT 1070 C , 10 min ,
AIR

HYDROSTATIC TEST 96 BAR , 1400 PSI

- CONTINUED *-*

(6a)

ON EACH TUBE: SATISFACTORY

MATERIAL IDENTIFICATION ON EACH PIPE: SATISFACTORY,,

MATERIAL IS FREE OF MERCURY CONTAMINATION.,,

NO WELD REPAIR HAS BEEN PERFORMED ON MATERIAL.,,

INTERGRANULAR CORROSION TEST ACC.TO ASTM A262 PRAC.E: O.K.,,
INTERGRANULAR CORROSION TEST ACCORDING TO MIL-P-24691/3,,
(SENSITIZED 675 C (1250 F) / 1 HOUR / AIRCOOLED):O.K.,,
THE TUBES CONFORM ALSO TO NACE STANDARD MR0175-2003/MR0103-2005

WE CERTIFY THAT THIS MATERIAL HAS BEEN MANUFACTURED,,
AND EXAMINED IN ACCORDANCE WITH ALL REQUIREMENTS OF,,
THE SPECIFICATION AND ORDER CONFIRMATION AND THAT THE,,
RESULTS OF ALL EXAMINATIONS ARE ACCEPTABLE.,,

MARKING: SBS - ,,

DIMENSION - HEAT NO. - LOT NO. - SMLS,,

STEELMAKING PROCESS: EF + AOD,,

ABBREVIATIONS:,,

RP0.2 = YIELD STRENGTH

RM = TENSILE STRENGTH

A2" = ELONGATION

KG = GRAIN SIZE,,

CONVERSION:,,

1 MPA = 1 N/MM = 145.037 PSI

CHEMISTRY

C	SI	MN	P	S	CR	MO
0.013	0.32	1.59	0.026	0.002	18.15	0.17
NI	C	SI				
10.25	0.020	0.35				

CHEMISTRY

MN	P	S	CR	MO	NI
1.58	0.025	0.005	18.66	0.18	10.49

MECHANICAL

Hardness Rockwell B	ROCKWELL-B	74	
	ROCKWELL-B	73	
Temperature	TEMPERATURE	20	CC
Yield strength ASTM	YIELD	268	MPa
Tensile strength	TENSILE	589	MPa
Elongation ASTM	ELONGATION	53	%
	ELONGATION	53	%
Tensile strength	TENSILE	574	MPa
Yield strength ASTM	YIELD	258	MPa
Temperature	TEMPERATURE	20	CC

QUALITY ASSURANCE CONTACT

Josef OFENBOECK

Schoeller-Bleckmann Pipe & Tube Inc

THIS INFORMATION WAS RECEIVED ELECTRONICALLY FROM THE MANUFACTURER IDENTIFIED ABOVE.

*-- END OF REPORT *--

2/2

PO#BL-2387
Item#1

PO: 0280255 Item #: 0010
HeavC of C: II-306073/II-14
Part: 064-302-SP0400 OMI

OmegaFlex Inc.

Hose Certificate of Conformance

DATE RECEIVED 11/3/2008 OMEGAFLEX PART 302-SP0400
ALLOY 321 GAUGE 0.0160 in. WIDTH 12.8300 in.
HEAT NUMBER I-827468 MASTER/LOT TAG# AL8885 COIL/HOSE TAG# II-306073
WEIGHT 0.00 Lbs. SPECIFICATION# OMIS-200 SPECIFICATION REVISION# E

CHEMISTRY (WEIGHT PERCENT)

C <u>0.0200</u>	Mn <u>1.7700</u>	P <u>0.0270</u>	S <u>0.0001</u>	Si <u>0.4800</u>	Cr <u>17.3000</u>	Ni <u>9.3000</u>
Mo <u>0.0090</u>	Cu <u>0.0000</u>	Co <u>0.0000</u>	Ti <u>0.2100</u>	N <u>0.0100</u>	Al <u>0.0000</u>	Fe <u>0.0000</u>
Zn <u>0.0000</u>	Mg <u>0.0000</u>	Cb <u>0.0000</u>	Ta <u>0.0000</u>	Sn <u>0.0000</u>	V <u>0.0000</u>	W <u>0.0000</u>
Pb <u>0.0000</u>	B <u>0.0000</u>					

Mechanical and Physical Properties

TENSILE 86500 psi YIELD 34400 psi ELONGATION 66 %
HARDNESS TEST TYPE 15T GRAIN SIZE 9.0
HARDNESS TEST RESULT 80.0 CARBIDE RATING # N/A BEND TEST RESULT N/A

CHEMICAL ANALYSIS AND MECHANICALS ARE TAKEN FROM THE RAW MATERIAL SUPPLIER'S TEST CERTIFICATE

Reviewed by

Dan W. Rivest P.E.



6870 HIGHWAY 42 EAST

6870 HIGHWAY 42 EAST

METALLURGICAL TEST REPORT

NORTH AMERICAN STAINLESS
6870 HIGHWAY 42 EAST
GHENT, KY 41045

Certificate: 447982 4

Customer: 000570 021

ALRO METALS SERVICE CENTER
CUSTOMER PICKUP
P.O. BOX 764
821 SPRINGFIELD STREET
DAYTON, OH 45401

Your Order: 6740178

NAS Order: WN 0009540 01

SHIP TO:
ALRO METALS SERVICE CENTER
CUSTOMER PICKUP
P.O. BOX 764
821 SPRINGFIELD STREET
DAYTON, OH 45401

Date: 1/26/2009 Page: 1

Finish: 2B

PRODUCT DESCRIPTION:

STAINLESS STEEL COIL, C.R. ANNEALED & PICKLED, UNS 30400
ASTM A240/08, A480/08a, A666/03; ASME SA240/07, SA480/07, SA666/07
CHEM ONLY ON FOLLOWING ASTM: A276/06a, A479/01, A484/06b, A312/07
AMS 5513H MARK; MIL-S-5059D AMENDS (X CROWN MEAS)
NACE MR0175/01, MR0103/07; Q08766D-A X MAG PERM
MIN. SOLUTION ANNEAL TEMP 1900F, WATER QUENCHED

REMARKS:

Mat'l is Free of Mercury Contamination. No weld repairs.
EN 10204:2004 3.1; Q08763Y Cond A; ROHS Compliant
Material is Free of Radioactive Contamination
NAS Steel Making Process: EAF, AOD, & Cont. Casting
Product Mfg. by a Quality Mgt. Sys. in Conf. w/ISO 9001:2000
*Melted & Manufactured in the USA; Mat'l is DEARS Compliant
EN10204 3.1b

Corrosion: ASTM A262/02aE, 180Bend-OK

Product Id	Coil #	Std #	Thickness	Width	Weight	Length	Mark	Pieces	Commodity Code
044TR4 AB	044TR4 A		.1163	48.0000	4.836	120.00	1	25	14816840

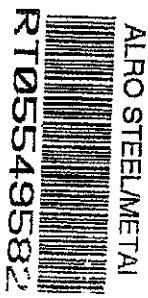
CHEMICAL ANALYSIS

CM(Country of Melt) ES(Spain) US(United States) ZA(South Africa) JP(Japan)

HEAT	CM	C	CR	CU	MN	MO	N	NI	P	S
4TR4	US	.0430	18.1220	.5035	1.5690	.0195	.0588	8.1355	.0315	.0010
		SI								
		.2935								

MECHANICAL PROPERTIES

Product Id#	Coil #	Id	UTS	.2% YS	ELONG	Hard	Tail
044TR4 AB	044TR4 A	F T	93.86	45.58	51.20	85.50	83.00



ALRO STEELMETAL
RECEIVED
SUBJECT TO COUNT INSP.

I hereby certify that the analysis on this certification is correct and the
vial fits the specifications stated.

QC ENGINEER

ERIC HESS

1/26/2

**VINOX CORPORATION**Phase II Block 5, Cavite Export Processing Zone Authority, PEZA,
Rosario, Cavite, Philippines 4106

TEL : +63-46-437-2995 ~ 98 FAX : +63-46-437-1027

MILL TEST REPORT

PURCHASER : SILBO INDUSTRIES, INC.

DATE : 2009/04/20

P. O. NO.: 98693

S/C NO.: 1452SIL

PRODUCT : STAINLESS STEEL BUTT WELD FITTING

HEAT NO.	Q'TY.	DESIGNATION	SPECIFICATION
8BCC1 ✓	359	304L/304 W 1" 90 ELBOW LR 10S	ANSI B16.9-07

CHEMICAL ANALYSIS OF MATERIAL

HEAT NO.	C	Mn	Si	P	S	Cr	Ni	Mo	N	SPECIFICATION
Maxi	0.030	2.00	1.00	0.045	0.030	18 - 20	8 - 13		0.100	A/SA403/07A
8BCC1	0.025	1.60	0.41	0.029	0.003	18.30	8.10		0.044	ASTM ASME WP-W

MECHANICAL CHARACTERISTICS

HEAT NO.	T.S-PSI	Y.S-PSI	%-E.L.	%-R.A.	HEAT-TREAT.	DIMENSION	P.M.I.
Mini	70,000	25,000	30		1050 - 1150 °C		
8BCC1	91,200	41,400	52		1060 °C	OK	OK

MATERIAL RESISTANT TO INTERCRYSTALLINE CORROSION ICC TEST
ACCORDING TO ASTM A262 PRACTICE E. FREE FROM MERCURY
CONTAMINATION. MATERIAL IN ACCORDANCE WITH NACE MRO 175-2003,
MRO 103-2003 & MRO 103-2007 ISO 9001:2000, PED 97/23/EC
CERTIFIED. EN10204 3.1

S3460F

FACTORY INSPECTOR:


EDWIN CAMPOS

QUALITY ASSURANCE DEPARTMENT

SM-005-0

NI/VO

9

ADDRESS: NO.50 Shenshen Road
The Administrative Committee of New&High
Tech Industrial Park, CHDZ, Jiangsu, China

PURCHASER: SILBO INDUSTRIES, INC.

COMMODITY: STAINLESS STEEL BUTT
WELD PIPE FITTINGS

MATERIALS: ASTM A312-2008

CSYC

Changshu YungChia Hardware
Fittings Enterprise Co., Ltd.

INSPECTION CERTIFICATE

SPEC: ASME/ASTM A/SA403-07a WP304/304L -W
ASME/ANSI B16.9-07

TEL: 86-512-52842266
FAX: 86-512-52842277

PAGE: 3 OF 7

DATE: 2009.11.04

ORDER NO.: CS090808

MFG. NO.: PO-200908-006

CERTIFI. NO.: PO-200908-005

L/C NO.:

ISO 9001:2000, NACE MRO-175/ISO 15156, NACE MRO103-2007, EN10204 3.1B, PED97/23/EC

P.O.: 99314

ITEM NO.	DESCRIPTION	Q'TY	HEAT NO.	RAW MATERIAL HEAT NO.	SURFACE & APPEARANCE INSPECTION	DIMENSION INSPECTION
008	90° ELBOW SR SCH 10S 304L 2 1/2"	53	099157200	252300	GOOD	GOOD
009	90° ELBOW SR SCH 10S 304L 2 1/2"	47	097184200	252300	GOOD	GOOD
010	45° ELBOW LR SCH 10S 304L 1 1/4"	75	093022V12	VLH111712	GOOD	GOOD
011	TEE SCH 10S 304L 1/2"	40	094069V08	VLH101708	GOOD	GOOD
012	TEE SCH 10S 304L 1"	125	096178V21	VLK040321	GOOD	GOOD
013	RHD-TEE SCH 10S 304L 1 1/4" x 1"	4	07A846V61	VLE101861	GOOD	GOOD
014	RHD-TEE SCH 10S 304L 1 1/2" x 1/2"	3	07A203V23	VLH041023	GOOD	GOOD
015	RHD-TEE SCH 10S 304L 1 1/2" x 1/2"	7	094038V87	VLK020087	GOOD	GOOD
016	RHD-TEE SCH 10S 304L 3" x 2 1/2"	8	096186249	250749	GOOD	GOOD
017	RHD-TEE SCH 10S 304L 3" x 2 1/2"	2	098029200	252300	GOOD	GOOD

STANDARD ITEM NO.	CHEMICAL COMPOSITION (%)								PHYSICAL TENSILE PROPERTY (%)			
	C MAX.	SI MAX.	Mn MAX.	P MAX.	S MAX.	Ni	Cr	Mo	YIELD STRENGTH N/mm ²	TENSILE STRENGTH N/mm ²	ELONGATION	HARDNESS TEST HRB
304/304L	0.035	1.00	2.00	0.045	0.030	8-11	18-20	-----	170	485	%	
008	0.021	0.390	1.44	0.030	0.005	8.10	18.17		272	607	49.00	74
009	0.021	0.390	1.44	0.030	0.005	8.10	18.17		272	607	49.00	76
010	0.018	0.440	1.39	0.036	0.007	8.08	18.21		283	622	50.00	73
011	0.025	0.390	1.44	0.033	0.005	8.08	18.18		274	610	51.00	78
012	0.017	0.360	1.45	0.031	0.010	8.02	18.12		284	628	49.00	74
013	0.019	0.400	1.46	0.029	0.011	8.15	18.38		278	605	52.00	78
014	0.020	0.400	1.47	0.037	0.005	8.01	18.22		281	642	50.00	71
015	0.024	0.400	1.48	0.039	0.002	8.09	18.06		292	643	50.00	77
016	0.025	0.440	1.35	0.040	0.004	8.04	18.32		288	627	49.00	75
017	0.021	0.390	1.44	0.030	0.005	8.10	18.17		272	607	49.00	78

REMARKS: HEAT TREATMENT AT 1060°C (1940°F) ± 20°C.

FOR 8 MINUTES MINIMUM TIME AND WATER QUENCHED.

Material is manufactured Mercury Free and free from Mercury contamination.
WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MADE
IN ACCORDANCE WITH THE ABOVE SPECIFICATION AND ALSO WITH THE
REQUIREMENTS CALLED FOR BY THE ABOVE ORDER AND IS THAT WHICH HAS
BEEN TESTED TO THE SATISFACTION OF THE INSPECTOR.



10

Customer SOUTHWEST STAINLESS ATLANTA

MATERIAL TEST & INSPECTION CERTIFICATE

SUNGKANG BEND CO., LTD.
172A SUNGBONG-DONG, GANSEO-KU, BUSAN 60012
http://www.srbend.com
TEL: 82-051-3300-450
FAX: 82-051-3300-335

According to DIN 50049 3.1 B / EN 10204 3.1 B / ISO 10474 3.1 B

Date of Issue: 2003/11/25

Job No. Spec. for Material

Spec. for Inspection

Visual & Dimension

P.O. No.

Certificate No.

A/S4403HP304/304L-S

ASME B16.9

SATISFACTORY

418761

OCL-200311171819

Manufacture No.

MADE FROM

Description

Size

Quantity

Heat Treatment

STEEL PLATE

CAP B.W

3/4" x 1" x 11/2"

225EA

SOLUTION TREATED.

Raw Material Maker

Raw Material Heat No.

Mfg. Heat ID No.

Test Piece size

N.D.E.

1060 C Hold 20MIN.

POSCO

T74877

T74877

ASTM A370 TEST PIECE

N/A

Heat

Chemical Composition(%)

Tensile Test

Bending Test

Hardness

Impact Test

STD

C

Si

Mn

P

S

Ni

Cr

Mo

Cu

V

Cb

C.B

Y.S

T.S

E.L.

R.A.

Test

Test

Test

Test

Test

Test

SMP

Min

Max

0.035

1.00

2.00

0.045

0.030

8.00

18.00

11.00

20.00

9.57

18.50

41.4

85.7

55.0

28.0

28.0

28.0

28.0

28.0

28.0

SMP

Max

0.021

0.57

1.17

0.024

0.004

9.57

18.50

41.4

85.7

55.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

SMP

Min

0.021

0.57

1.17

0.024

0.004

9.57

18.50

41.4

85.7

55.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

SMP

Min

0.021

0.57

1.17

0.024

0.004

9.57

18.50

41.4

85.7

55.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

28.0

WE CERTIFY THIS MATERIAL HAS BEEN MANUFACTURED AND EXAMINED IN ACCORDANCE WITH ALL REQUIREMENTS OF THE SPECIFICATION AND THE RESULTS OF ALL EXAMINATION ARE ACCEPTABLE.

Reviewed By
Witnessed ByS/105 : 3/4" SEA
1.60EA
11/2" 60EA
S/405 : 3/4" 25EA
1.25EA
11/2" 50EAQUALITY MANAGEMENT DIVISION
KHSK / CH

SKE-8903

SUNGKANG BEND CO., LTD.

MANAGING DIRECTOR

3/4" x 1" x 11/2" S40 304 CAP

T74877

HEADQUARTERS:
1001 EAST WATERFRONT DR.
MUNHALL, PA 15120
PHONE 412-462-2185
FAX 412-462-4189



MARCCEGAGLIA

CERTIFICATE OF TEST

ROBERT JAMES SALES, INC.
1301 EAST WATERFRONT DR.
MUNHALL, PA 15120
PHONE 412-462-2185
FAX 412-462-4189
DATE 12-15-09
TEST NO. CH6346

ROBERT JAMES
PO BOX 7999
2585 WALDEN AVE
BUFFALO, NY 14225-7999

ROBERT JAMES
2585 WALDEN AVENUE
BUFFALO, NY 14225

TEST NO. CH6346
MARK NO.

FLAT	HYDRO	FLAT	FLAT	EDDY	RND	RLT
OK	OK	OK	OK	OK	OK	OK

NETWORK DURING ITS MANUFACTURE AND PROCESSING. BRITANT ANNEALED
EN 10206 SEC. 3.1.B
COUNTRY OF MEXICO/COUNTRY OF MEX.-USA

MILL ORDER NO.	227887-01
PURCHASE ORDER NO.	AP1278
DATE SHIPPED	11/13/2009
SPECIFICATIONS	ASTM A312-08 AND ASME SA312-08 WELDED MACE MRO-175 B3/MACE MRO-103 03
OTHER SPECIFICATIONS	

WE CERTIFY THAT THIS MATERIAL IS FREE FROM
MERCURY CONTAMINATION & CONTIGUOUS CARBIDE

ITEM	TYPE	OR/IPS	YASCH	HEAT NO.	CARBON	MANG.	PHOS.	SULPHUR	SILICON	CHROMIUM	NICKEL	MOLY	COPPER	COBALT	TI	N
03	TP304/TP304L	3-1/2"	5	401313	.026	1.35	.024	.013	.44	18.11	8.18	.23	.35	.13		
05	TP304/TP304L	1"	18	4V17	.018	1.71	.031	.011	.27	18.18	8.18	.45	.53			
05	TP304/TP304L	1"	18	829979	.019	1.85	.029	.012	.56	18.40	8.16	.33	.48	.39		
09	TP316/TP316L	1"	48	828889	.018	1.59	.032	.011	.43	16.38	10.18	2.87	.44	.53		
09	TP316/TP316L	1"	48	829835	.016	1.58	.031	.011	.44	16.78	10.28	2.89	.37	.32		

ITEM	ROCKWELL HARDNESS	YIELD STRENGTH (PSI)	TENSILE STRENGTH (PSI)	ELONGATION	HYDRO PSI (# APPLICABLE)	MELT SOURCE (# APPLICABLE)	PIECES	FOOTAGE
03	880	49,988	88,588	61.3		0	36	680'
05	886	48,288	88,488	61.3		0	48	1828'
05	884	48,288	88,988	61.3		0	96	2948'
09	883	49,888	98,288	61.3		0	24	518'
09	81	46,888	87,888	57.5		0	72	1538'

**ISO 9001:2008
CERTIFIED**

FOR BAA, COMPLETE, CANNOT CERTIFY COMPLIANCE
FOR BAA, COMPLETE, CANNOT CERTIFY COMPLIANCE
FOR TAA, COMPLETE, CANNOT CERTIFY COMPLIANCE

WE CERTIFY THAT THE CHEMICAL,
PHYSICAL OR MECHANICAL TESTS
REPORTED HEREIN ARE CORRECT
AS SHOWN ON OUR RECORDS.

David Roeder
Q.C. MANAGER



ENLIN STEEL CORPORATION

MILL TEST REPORT

DATE: Jan/16/2001

PURCHASER: H & H MACHINE COMPANY, INC.

PURCHASE ORDER NO.:

ENLIN SC NO.: A370H&H

PRODUCT : STAINLESS STEEL BUTT WELD FITTING

HEAT NO.	QTY	TYPE	DESIGNATION	SIZE	SPECIFICATION
0181	89	304L/304	S-10 CAP	1"	ANSI B16.9-93

CHEMICAL ANALYSIS OF MATERIAL

HEAT NO.	C	Mn	Si	P	S	Cr	Ni	Mo	N	SPECIFICATION
Maxi	0.035	2.00	1.00	0.040	0.030	18- 20	8- 11	-		A/SA403/97A
0181	0.021	1.37	0.36	0.022	0.012	18.36	10.18			ASTM ASME WP-W

MECHANICAL CHARACTERISTICS

HEAT NO.	TS.-PSI	YS.-PSI	%-EL.	%-RA.	HEAT-TREAT	DIMENSION	P.M.I.
Mini	75,000	30,000	30		1050- 1150 °C		
0181	87,000	36,000	63		1060 °C	OK	OK

MATERIAL RESISTANT TO INTERCRYSTALLINE CORROSION ACCORDING TO
ASTM A262 PRACTICE E.
FREE FROM MERCURY CONTAMINATION.
MATERIAL IN ACCORDANCE WITH NACE MR0175-94.

FACTORY INSPECTOR :

J. J. Lin

QUALITY ASSURANCE DEPARTMENT



東豐工業股份有限公司 TUNG FONG INDUSTRIAL CO., INC.

Tel: +63-46-4371036,37
+63-46-9710301
Fax: +63-46-4371038
+63-46-9710302

Phase III, Lot 10 and 12, Block 19,
Philippine Economic Zone Authority,
Rosario, Cavite, Philippines

Order.No.: 98692
Ref.No.: T08-S19-PI01
Cert. No.: 101460-F
Date: 2009/05/08

Mill Test Certificate

1. Commodity: STAINLESS STEEL B.W. PIPE FITTINGS
2. Purchaser: SILBO INDUSTRIES, INC.
3. Material: ASTM A240 STAINLESS STEEL PLATES
4. Specification: ASTM/ASME A/SA403WP-2003 ANSI B16.9-2007 ANSI B16.25 WP304/304L-S

Item No.	Order Size				Description of Test			Pcs	Heat No.	Pipe Heat No.
					Surface & Dimension	Hydrostatic	Flattening			
30.	Cap	wp-s	304/304L	sch10s 1"	Good		N/A	30	T36378	T36378
31.	Cap	wp-s	304/304L	sch10s 1-1/2"	Good		N/A	75	T36378	T36378
32.	Cap	wp-s	304/304L	sch10s 2"	Good		N/A	250	T36378	T36378
33.	Cap	wp-s	304/304L	sch10s 2-1/2"	Good		N/A	30	139308	139308
34.	Cap	wp-s	304/304L	sch10s 3"	Good		N/A	200	139308	139308
35.	Cap	wp-s	304/304L	sch10s 5"	Good		N/A	50	YU154719	YU154719
36.	Cap	wp-s	304/304L	sch10s 6"	Good		N/A	100	YU154719	YU154719

Item No.	Mechanical (Physical) Property				Chemical Property							
	Yield Point	Tensile Strength	Hardness	Elongation	C	Mn	P	S	Si	Ni	Cr	Mo
	MPa	MPa	HRB	%	% (x1000)	% (x100)	% (x1000)	% (x1000)	% (x100)	%	%	%
30.	286.0	599.0	67.9	58.5	21	177	30	3	42	8.20	18.30	
31.	286.0	599.0	67.9	58.5	21	177	30	3	42	8.20	18.30	
32.	286.0	599.0	67.9	58.5	21	177	30	3	42	8.20	18.30	
33.	289.0	601.0	65.0	54.0	24	125	29	2	40	8.12	18.60	
34.	289.0	601.0	65.0	54.0	24	125	29	2	40	8.12	18.60	
35.	280.7	601.3	81.0	49.0	17	144	22	5	41	8.25	18.17	
36.	280.7	601.3	81.0	49.0	17	144	22	5	41	8.25	18.17	
	205.0	515.0	90.0	40.0	30	200	45	30	100	8.00	18.00	
	Min	Min	Max	Min	Max	Max	Max	Max	Max	10.00	20.00	

THIS IS TO CERTIFY THAT ABOVE PRODUCTS ARE IN CONFORMITY WITH MECHANICAL(PHYSICAL) AND CHEMICAL PROPERTY INDICATED ABOVE. THE FITTINGS CONFORM IN EVERY WAY TO ASTM/ASME A/SA403 2003 WP304/304L AND TO ANSI B16.9-2007 ANSI B16.25 SPECIFICATION. HEAT TREATMENT AT 1050 DEGREE CENTIGRADE AND WATER QUENCHED. ALL GRADES OF THE MATERIAL HAS BEEN FURTHER VERIFIED TO BE MERCURY FREE AND NO WELD REPAIRS WERE PERFORMED. HARDNESS TO NACE MRO175-2003 AND NACE MRO103-2003 INTERCRYSTALLINE CORROSION ACCORDING TO ASTM/TYP E. CERTIFIED ACCORDING TO EN10204/3.1.B. PMI TESTED.

S3460E
TUNG FONG HAS ESTABLISHED A QMS ACCORDING TO ISO 9001, CERTIFIED BY TUV CERT.(01-100-089316) WITH PARTICULAR MATERIAL APPRAISAL PER BVQI CERT. (CE-PED-PMA-TFI001-08-TWN). COUNTRY OF ORIGIN ON ALL PIPES USED WITH HEAT NUMBERS AS INDICATED ABOVE IS TAIWAN.

ORIGINAL


NI/NO

TUNG FONG INDUSTRIAL CO., INC.

Chief of Inspection Dept.

v10.18.12 150 / 424

Page 1

	CERTIFICADO DE TESTE DE MATERIAL Inspeção Certificate 3.1 / Certificado de Inspeção 3.1 acc. to / nach DIN EN 10 204 / ISO 10474		Schulz America Latina Fábrica Campos Quality Assurance Garantia de Qualidade
	Page Date: 25.07.2007 Certificate No. / Certificado n.º: 100093 Revision / Revisão: 0	Página Data: 25.07.2007 Certificado n.º: 100093 Revisão: 0	1 of 2

Firma
 SCHULZ USA INC
 5700 CLAYMOORE PARK, DR., SUITE 100
 HOUSTON, TEXAS
 USA

Our Order:	Nossa ordem:	USA000073
Our Item:	Nosso item:	\$
Your P.O.	Seu pedido:	
Your Item:	Seu item:	
Our Ref.:	Nossa ref.:	copio

Component / Produto

Description:	Descrição:	Tee equal, Welded	Marking / Marcação P M I A 403 WP304/304L - W 304804 1" SCH 10S Brazil Manufacturing Date / Data de Fabricação PT000499
Material Grade:	Tipo Material:	WP304/304L	
Class:	Classe:	W	
Quantity:	Quantidade:	425 Pcs / Pç	
Dimensions:	Dimensões:	1" SCH 10S	
Requirements / Especificações do produto Base Material: Material base: ASTM A 312/SA 312 Product form: Produto: ASTM A 403/A 403M - 08, NACE MR0175/ISO 15156-3:2003(E) ASME B16.3-2003 Welding level: soldabilidade ASME B16.3-2003 Fig. 2(a) Cold formed: Conformado a F			

Heat Treatment / Tratamento térmico

solução aquecida / Tratamento Térmico 1050 °C 15-40 °F 15 min resfriado em água / resfriado em água

Chemical Composition / Composição química

Melting Process / Tipo de Fundição:				SIA00				
Heat		C	Mn	P	S	Si	Cr	Ni
Heat	304804	0,018	1,40	0,028	0,008	0,38	18,1	9,1

Mechanical Properties / Propriedades mecânicas

Tensile Test / Ensaio Mecânico

Test No.	Charge	specimen / Probe		Test Temp.	Yield Strength		Tensile Strength		Elongation	Reduction			
		Location	Or		Size	Rp0.2 %	Rp1.0 %	Rm			AS0		
				mm	°C	°F	(N/mm²)	KSI	(N/mm²)	KSI	%	%	
BRX075875-05	304604	B	T	Std	20	68	236.00	43.22	336.00	47.88	558.00	51.08	51.0

Tests de dureza


Rockwell C: < 20

DIN EN ISO 9001:2008

Schulz America Latina Imp. e Exp. Ltda, Rua Alcy Ferreira, 61/408, Distrito Industrial COBOL, CEP: 38090-410
 Campos dos Goytacazes, RJ, Brasil, Tel - 55(22)32112008 Fax - 55(22)32112141

160a

Page 2

	CERTIFICADO DE TESTE DE MATERIAL Inspection Certificate 3.1 / Certificado de Inspeção 3.1 acc. to / nach DIN EN 10 204 / ISO 10474	Schulz America Latina Fábrica Campos Quality Assurance Garantia de Qualidade	
		Page Data: Certificate No. Revision	Página Data: Certificado n°: Revisão:

Mandatory Tests / Testes padrões

Positive Material Identification / Identificação Positiva do Material (PMI)	Base and filler metal (if applicable): satisfactory Material de base e metal de solda (se aplicável): satisfatório
Visual and Dimensional Control / Controle Visual e Dimensional	without complaints / Satisfatório

Metallurgical Requirements / Requisitos Metalúrgicos

Corrosion Resistance / Resistência à Corrosão	ASTM A 262 PRACTICE E: Satisfactory / Satisfatório
---	--

The material is free from low-melting-point material and radioactive contamination.
 Este produto não contém material de ponto de fusão baixo ou de contaminação radioativa.

This testimonial and certification is recorded by computer system and is valid without signature. Alteration or use for other products are regarded as falsification of documents and will be subject to criminal jurisdiction.
 Este certificado/documento foi criado por meio eletrônico e por isso é válido sem assinatura. Modificações e uso para outros produtos é falsificação e fraude e responderá perante a lei.

THIS IS TO CERTIFY THAT THE CONTENT OF THE REPORT IS CORRECT AND ACCURATE AND THAT ALL TEST RESULTS AND OPERATIONS PERFORMED BY SCHULZ OR ITS SUBCONTRACTORS ARE IN COMPLIANCE WITH THE MATERIAL SPECIFICATIONS LISTED IF SO STATED ELSEWHERE IN THIS CMTR AND WAS FOUND TO MEET THE REQUIREMENTS. WE HEREBY CERTIFY THAT THE MATERIAL USED FOR PRODUCT FORM CONVERSION CONFORMS TO THE APPLICABLE DIMENSIONAL REQUIREMENTS.

Certificamos que o conteúdo deste relatório está correto e confiante com os resultados dos testes e operações feitas pela Schulz ou seus subcontratados de acordo com as especificações listadas neste certificado. Certificamos que o material usado para conversão de forma do produto atende as exigências das normas e está apto e íntegro para uso dentro das condições e especificações da norma.

25.07.2007

Décio Antonelli

Date Authorized Inspection Representative
 Data Representante de Inspeção autorizado

DIN EN ISO 9001:2000

Schulz America Latina Ltda. e Exp. Ltda, Rua Aloy Ferraz, 814-00, Distrito Industrial CODIN, CEP: 28060-410
 Campos dos Goytacases, RJ, Brazil. Tel.: 55(22)32112000 Fax: 55(22)32112141

166

Purchaser: SILRO INDUSTRIES, INC.
 Order No: 95628/S2280A
 Invoice No: ERH-067-2
 B/I. No: SHUSA518202
 FLANGE FACES TO BE 125-250RMS

MILL'S CERTIFICATE
 WUXI HUAN FLANGES CO., LTD.
 HUAXI VILLAGE, WUXI JIANGYIN CITY JIANGSU, P.R. CHINA 214421
 ACCORDING TO EN10204 3.1 PED 97/23/EC
 Specification
 For Material: STAINLESS STEEL ASTM A/S182 F304/ 304/L
 MANUFACTURE IS CERTIFIED ISO 9001:2000
 Specifications
 For Inspection: ANSI B16.5
 SEC. II PART A (1989) ISO9002 NACE MR0175-

522806
 DATE: MAY 18 2007
 Page: 1 OF 1
 Certificate No.: 070518

No.	Mfg No.	Description	Quantity	Visual Dimensional Inspection	Bend Test Form (1.5) result 180°	Hardness MAX 217	Magnetic Particle Examination
1		FLANGE SORF 304/L 20" 150LBS	10 PCS	GOOD	GOOD	150	GOOD
2		FLANGE SORF 304/L 24" 150LBS	175 PCS	GOOD	GOOD	147	GOOD
SPECIFICATIONS							
CHEMICAL COMPOSITION (%)							
No.	Heat No.	Min	C	Si	Mn	P	S
			x 1000	x 100	x 100	x 1000	x 1000
1	ZT0092	30	75	200	45	30	12
2	ZT0081	20	39	164	40	9	8.09
		18	37	182	40	12	8.06
Tension Test							
Y. S							
MPa							
		170	485	50	40		
		270	585	72	58		
		270	585	70	56		
Material Manufacturer							
HEAT TREATMENT							
C H C H C H C H							
NORMALING SOLUTIONING 1040 °C							

WE HEREBY CERTIFY THAT THE FITTINGS LISTED ABOVE WERE MANUFACTURED IN STRICT CONFORMANCE WITH
 AS SPECIFICATIONS. THE ABOVE RESULTS OF TENSILE STRENGTH TESTS AND CHEMICAL ANALYSIS ARE
 TRUE AND CORRECT COPY OF THE TEST CERTIFICATE ISSUED BY THE MANUFACTURER OF THE MATERIAL.
 MERCURY FREE AND FREE FROM CONTAMINATION.

MANAGER OF QUALITY



SHUANG LI GROUP CO., LTD.
MILL TEST CERTIFICATE
(ACCORDING TO EN 10204 3.1B)

CEPVI REGISTRATION NUMBER: TS270778-2010

Industry Service Management Service

ORDER NUMBER: 98690
S3460C
Date: 2009/06/18

STAINLESS STEEL BUTT WELD FITTINGS CONFORMING WITH SA 403 WP-W/ASTM A 403-00B T304/304L OR T316/316L DIMENSIONAL TOLERANCES

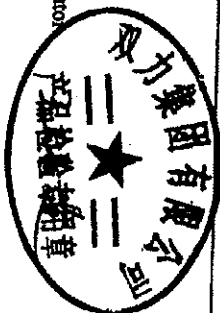
Item No.	Material	Description	Size	Qty	Heat No	CHEMICAL COMPOSITION(%)										Mechanical Properties			Visual Inspection	Heat Treatment	Hardness HB	Intergranular Corrosion
						C	Si	Mn	P	S	Ni	Cr	Mo	Ti	Tensile Strength Mpa	Yield Point Mpa	Elongation %					
1	304L-S	SCH10S WT-0.250" CAP	24"	24	BB070051	0.016	0.37	1.28	0.022	0.002	8.13	18.17			720	375	60	GOOD	GOOD	GOOD	GOOD	
2	304L-WX	SCH10S CON RED	30"x20"	10	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
3	304L-WX	SCH10S CON RED	30"x24"	6	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
4	304L-WX	SCH10S CON RED	36"x24"	4	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
5	304L-WX	SCH10S ECC RED	30"x24"	6	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
6	304L-WX	SCH10S ECC RED	36"x20"	2	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
7	304L-WX	SCH10S ECC RED	36"x24"	2	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
8	304L-WX	SCH10S ECC RED	36"x30"	1	BB070127	0.023	0.51	1.82	0.026	0.002	8.01	18.05			615	315	56	GOOD	GOOD	GOOD	GOOD	
9	304L-WX	SCH10S L.R 90 ELBOW	20"	2	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
10	304L-WX	SCH10S L.R 90 ELBOW	24"	4	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
11	304L-S	SCH10S CAP	14"	5	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
12	304L-S	SCH10S CAP	20"	10	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
13	304L-S	SCH10S CAP	24"	4	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
14	304L-WX	SCH10S CON RED	24"x18"	2	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
15	304L-WX	SCH10S CON RED	24"x20"	2	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
16	304L-WX	SCH10S ECC RED	16"x14"	2	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
17	304L-WX	SCH10S ECC RED	18"x16"	2	BB070090	0.020	0.40	1.31	0.020	0.001	8.18	18.30			660	340	49	GOOD	GOOD	GOOD	GOOD	
18	316L-WX	SCH10S L.R 90 ELBOW	30"	6	BB070104	0.026	0.60	1.42	0.025	0.003	10.19	16.01	2.11		590	240	65	GOOD	GOOD	GOOD	GOOD	
19	316L-WX	SCH10S SR 90 ELBOW	36"	2	BB070104	0.026	0.60	1.42	0.025	0.003	10.19	16.01	2.11		590	240	65	GOOD	GOOD	GOOD	GOOD	
20	316L-WX	SCH10S CAP	24"	4	BB070102	0.024	0.50	1.34	0.014	0.001	10.12	16.72	2.09		620	385	49	GOOD	GOOD	GOOD	GOOD	
REMARKS																						
MATERIAL IS DUAL CERTIFIED. MANUFACTURED TO AS4 403 WP/WPS. WPV MATERIAL WAS X-RAYED. MANUFACTURER IS CERTIFIED ISO9001:2000. MATERIAL IS NACE MR0175 COMPLIANT																						
MATERIAL IS NACE MR0100-2003 COMPLIANT. MATERIAL IS MANUFACTURED MERCURY FREE. AND FREE FROM MERCURY CONTAMINATION.																						
MATERIAL IS EN10204-3.1B COMPLIANT. MATERIAL IS PED 9723/REC CERTIFIED.																						

SHUANGJI GROUP CO.,LTD.

SHUANG LI GROUP CO., LTD.

ADD: NO.3566, TINWEI ROAD, JINSHAN
DISTRICT, SHANGHAI, CHINA
Tel: 86-21-67256666-8111 Tel: 67256660
Fax: 86-21-67256660

Quality Examiner





SHUANG LI (GROUP) CO., LTD
MILL TEST CERTIFICATE
(ACCORDING TO EN 10204 3.1B)



Institute Service

Management Service

ORIGINAL
ORDER NUMBER: 0078

S25604

Date: 2007/11/07

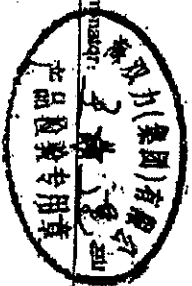
Page: 1/1

STAINLESS STEEL BUTT WELD FITTINGS CONFORMING WITH SA 403 WP-W/ASTM A 403-00B T304/304L OR T316/316L DIMENSIONAL TOLERANCES TO B16.9

Order No.	Item No.	Material	Description	Size	Qty	Heat No	CHEMICAL COMPOSITION(%)										Mechanical Properties			Visual Inspection	Dimension Inspection	Heat Treatment	Hardness HB	Intergovernmental Convention
							C	Si	Mn	P	S	Ni	Cr	Mo	Ti	Tensile Strength MPa	Yield Point MPa	Elongation %						
	1	304/L	SCH10S CAP	24"	20	B8070021	0.018	0.44	1.22	0.009	0.007	8.13	18.55			570	280	59	GOOD	GOOD	GOOD	GOOD	GOOD	
REMARKS																								
MATERIAL IS DUAL CERTIFIED. MANUFACTURED TO AMS 403 WPS. MATERIAL WAS X-RAYED. MANUFACTURER IS CERTIFIED ISO9001:2000. MATERIAL IS NACE MR0175 COMPLIANT																								
MATERIAL IS NACE MR0103-2M03 COMPLIANT. MATERIAL IS MANUFACTURED MERCURY FREE AND FREE FROM MERCURY CONTAMINATION.																								
MATERIAL IS EN10204-3.1B COMPLIANT. MATERIAL IS PED 9722ZFC CERTIFIED.																								
SHANGHAI SIUANGU (GROUP) CO.,LTD.																								

SHANGHAI SIUANG LI (GROUP) CO., LTD.
ADD: NO. 3566, TIANWEI ROAD, JINSHAN
DISTRICT, SHANGHAI, CHINA
Tel: 86-21-67256666-8111 Tel: 67256660
Fax: 86-21-67256660

Quality Examination



PUFA™

Premium Stainless Steel Seamless Tubes

Shanghai Pufa Stainless Steel Pipe Factory

MILL TEST REPORT

Purchaser: Robert-James Sales, Inc.				Certificate No.: 08-8-62					
Contract No.: R-James P.O. No.: AO1123				Date of Issue: 2008.8.31					
Commodity: Stainless Steel Seamless Tubes				Specifications: ASTM A213-07/ASME SA213-07/ASTM A269-07a EAW					
Process: Cold Drawn				Delivery Condition: OD Polished (240 Grit)					
Steel Grade	Heat Number	Lot Number	Dimensions	Quantity					
				Pieces	Quantity (ft)				
TP304/TP304L	YX0806-410	8-58	2" x 0.065" x 20'	54	1,080				
Chemical Composition by Weight (%)									
Element	C	Mn	P	S	Si	Cr	Ni	Mo	Co
Requirements	≤0.035	≤2.00	≤0.045	≤0.030	≤1.00	18.00-20.00	8.00-12.00		
Ladle Analysis	0.022	0.75	0.034	0.001	0.41	18.50	8.16		
Product Analysis	0.027	0.70	0.036	0.001	0.42	18.39	8.32		
Mechanical Properties									
Test Item	Elongation (% in 2")	Tensile Strength (MPa)		Yield Strength (MPa)					
		Rm		Rp / 0.2%					
Requirements	≥35	≥515		≥205					
Test Results	63/64	610/620		270/275					
Test Item	Reduction of Area Z (%)	Hardness	Cold Bend Test	Flaring Test	Flattening Test	Flange Test	P.M.I. Test		
Requirements		HRB ≤80		21%	α=0.89				
Test Results		76/78		Passed	Passed	Passed	OK		
Test Item	Eddy Current Test	Hydrostatic Test	Ultrasonic Test	Intergranular Corrosion Test	Macroscopic Inspection				
Requirements	ASTM E 426				End Cut	Appearance			
Test Results	Passed				OK	OK			

ISO 9001:2008 Certified by Moody International 118783068

In Compliance with EN 10204-3.1.B

Additional Remarks:

- (1) Materials is NACE MRO103-2003 compliant
- (2) Materials is NACE MRO175-2003 compliant
- (3) Materials is PED 97/23/EC certified
- (4) Tubes tested per ASTM A450-04a
- (5) All tubes annealed to above 1900 Deg F and water quenched below 800 Deg F in 3 minutes
- (6) No weld repair performed
- (7) Free from mercury contamination
- (8) Billets melt and pipes/tubes manufactured in China

We hereby certify that this report is true and correct.

By: Shanghai Pufa Stainless Steel Pipe Factory

Manager of Quality Control Department

PUFA™上海浦发不锈钢钢管厂
Shanghai Pufa Stainless Steel Pipe Factory

地址 (ADD) 上海市浦东新区王港镇红卫路7号 邮编 (ZIP) 201201

No. 7, Hongye Road, Wanggang Town, New Pudong District, Shanghai, P.R. China

20



METALLURGICAL TEST REPORT

NORTH AMERICAN STAINLESS
6870 HIGHWAY 42 EAST
GHEAT, KY 41045

6870 HIGHWAY 42 EAST
Certificate: 481942 1

Customer: 000570 039

ALRO METALS SERVICE CENTER
ALRO GROUP
P.O. BOX 927
JACKSON, MI 49204-0927

Your Order: 6913312

NAS Order: IN 0069483 01

SHIP TO:
ALRO METALS SERVICE CENTER
CUSTOMER PICKUP
COLUMBUS 555 ROME HIGHWAY
COLUMBUS, OH 43228

Date: 6/24/2009 Page: 1
Steel: 304L/304

PRODUCT DESCRIPTION:

Equal angles, hot rolled, annealed, pickled. ASTM-A-484-06B ANGLE UN
S S30400, S30403, ASTM A276/04, ASTM A479/04, QQS-763P, EN 10204 3
1B, ASME SA479/04

REMARKS:

Melted & Manufactured in the USA. Product complies w/ require
ments of EU directive 2002.95.EC. ROHS. Material Free from Mer
cury contamination. No weld repair. NAS certifies the analysis
is on certification is correct & the material meets specs st
ated.

Corrosion: ASTM A262-02a PRACTICE E-
Finish: EQANGHRAP

Product Id	Skid #	Thickness	Size	Weight	Length	Mark	Pieces	Commodity Code
VA6807 0		.3750	3.0000	1,240	252.00	1	1	18084000

CHEMICAL ANALYSIS

CM(Country of Italy) ES(Spain) US(United States) ZA(South Africa) JP(Japan)

HEAT	CM	AL	C	CO	CR	CU	MN	MO	N	NI
4HKL	US	.0029	.0254	.1833	18.2718	.4593	1.7440	.5249	.0695	8.1673
P	S		SI	TI						
		.0354	.0134	.3276	.0044					

MECHANICAL PROPERTIES

Product Id	1	2	3	4	5	6	7	8	9	10
VA6807 0	o	1	HB	.2	YS	UTS	RA	.1	YS	OKALLC ELO-2"
	o	r	No.	KSI	KSI	%		KSI	P/F	%
	CI	L	237.00	71.69	106.85	67.56	82.35	1.00	41.22	

ALRO STEEL/METAL



RT04809816

NAS hereby certifies that the analysis on this certification is correct and the
material meets the specifications stated.

QC ENGINEER

ERIC BESS

6/24/2009

CERTIFICATE OF TEST



Page 01 of 02

Certification Date
5-NOV-2009**CUSTOMER ORDER NUMBER**

BC-3175

EARLE M. JORGENSEN COMPANY
2060 ENTERPRISE PKWY.
P.O. BOX 970
TWINSBURG OH 44087Invoice Number
T550044**CUSTOMER PART NUMBER**

522153

SOLD TO: EDEN CRYOGENICS LLC8449 RAUSCH DR
PLAIN CITY OH 43064**SHIP TO:**

EDEN CRYOGENICS LLC

8449 RAUSCH DR
PLAIN CITY OH 43064**Description:** 304/304L HR ANN BAR ASTM A479

1/2 X 4 X 12' R/L

HEAT: 231105**ITEM:** 522153**Line Total:** 95.9646 LB**Specifications:**

ASTM A276 08A

QQ S 763 F

ASTM A370 09

ASTM A320 08

ASME SA193 07

ASTM A479 08

AMS 5639 H

ASTM A182 08A

ASME SA320 07

AMS QQ S 763 B

ASME SA479 07

AMS 5647 H

ASME SA182 07

ASTM A193 08B

NACE MR0175 03

CHEMICAL ANALYSIS

C	SI	MN	CR	MO	CU	NI	CO
0.03	0.52	1.45	18.0	0.54	0.68	8.1	0.09
P	S	N					
0.029	0.029	0.081					

RCPT: R833860**MILL :** VALBRUNA STAINLESS (BUYOUT)**COUNTRY OF ORIGIN :** USA**MECHANICAL PROPERTIES**

DESCRIPTION	YLD STR KSI	ULT TEN KSI	%ELONG IN 02 IN	%RED IN AREA	HARDNESS BHN
	45.0	90.0	60.0	68.0	179

GRAIN SIZE : 5 -

The above data were transcribed from the manufacturer's Certificate of Test after verification for completeness and specification requirements of the information on the certificate. All test results remain on file subject to examination.

We hereby certify that the material covered by this report will meet the applicable requirements described herein, including any specification forming a part of the description.

The willful recording of false, fictitious, or fraudulent statements in connection with test results may be punishable as a felony under federal statutes.

Material did not come in contact with mercury while in our possession.

JIM ROHN

22

MANAGER, QUALITY ASSURANCE

V10.18.12 1587424



BRITE LINE FLANGE DIVISION
 Jiangyin Shengda Brite Line Kasugai Flange Co., Ltd.
 Shashan Road, European Industrial Park
 Zhouzhuang Town, Jiangyin City
 P.R. China

BRITE LINE

DESCRIPTION	GRADE	HEAT CODE	C	SI	MN	P	S	NI	CU	MO	N	YIELD PSI	TENSILE PSI	% ELONG	RA %	HARDNESS HRC
14" 300 NF SO	F304/304L	YT080122	1	0.026	0.41	1.00	0.038	0.010	8.10	18.10	0.078	40,900	82,800	55	68	14
8" 300 RF WN 40S	F304/304L	YT080122	1	0.026	0.41	1.00	0.038	0.010	8.10	18.10	0.078	40,900	82,800	55	68	14
24" 150 BLD	F304/304L	YTB71241	1	0.018	0.27	1.22	0.040	0.016	8.12	18.16	0.058	42,900	81,400	59	68	15

STARTING MATERIAL: 1. FORGING 2. PRE WELDED WITHOUT FILLER METAL 3. PLATE 4. BAR 5. SEAMLESS PIPE 6. FILLER METAL

THESE BRITE LINE FLANGES HAVE BEEN PRODUCED IN ACCORDANCE WITH AND MEET THE REQUIREMENTS OF ASTM A182-08, ASME SA182-08 AND ANSI/ASME B16.5-08.
 THE MATERIAL WAS SOLUTION ANNEALED AT A MINIMUM OF 1900 DEGREES F AND WATER QUENCHED.
 THIS MATERIAL IS FREE FROM MERCURY CONTAMINATION.
 NO WELD REPAIR. MEETS NACE MR0175 / ISO 15156 AND NISO103-2005. REPORT IN ACCORDANCE WITH EN 10204 3.1.
 WE CERTIFY THAT THE MATERIAL REPRESENTED BY THIS DOCUMENT HAS BEEN INSPECTED AND TESTED, AND IS IN CONFORMANCE WITH THE REQUIREMENTS OF THE REFERENCED SPECIFICATIONS AND YOUR PURCHASE ORDER.
 THIS REPORT IS AUTHORIZED BY TIMOTHY P. WARREN, VICE PRESIDENT OF QUALITY ASSURANCE, CORE PIPE.
 REGISTERED ISO 9001:2000.

PHOENIX TUBE COMPANY, INC.

Manufacturer of Stainless Ornamental and Structural Tubing

CERTIFICATION OF TEST

Sold To: ALRO GROUP
555 ROME-HILLIARD

COLUMBUS, OH 43228
USA

Ship To: ALRO GROUP
555 ROME-HILLIARD

COLUMBUS, OH 43228
USA

CUSTOMER ORDER#: 7032589
DATE SHIPPED: 10/05/09
SIZE: 6" X 1/2" HRAP
SOURCE: USA D
VENDOR: NAS

Phone# 8787271 Ext:
ORDER#: 201584
QTY SHIPPED: 627.0
GRADE: 304 NO WELD: BAR
HEAT#: 5EX7
TEST REPORT#: TR008408
Report Date: 06/09/09

Specification:

CHEMISTRY THIS COLUMN:

ASTM A276-08 COND. A	ASTM A262, PRACTICE E	ASTM A240-09	TYPE 304
ASME SA276-08 COND. A	CORROSION OK, HRAP	ASME SA240-09	UNS# 30400
ASTM A479-08, S2.1	ASTM A484-08	MILS 5059D AMEND 3	ASTM A666-03
ASME SA479-08, S2.1	ASME SA484-08		
QQ-S-763F, COND. A	NO WELD REPAIR	ASTM A480-09	
QQ-S-766D, COND. A	EN 10204 3.1.B	ASME SA480-09	

MERCURY IS NOT USED BY US AS AN ALLOYING MATERIAL NOR IS METALLIC MERCURY HANDLED IN THE VICINITY OF OUR PROCESSING LINES. WE ARE NOT PRESENTLY AWARE OF ANY MERCURY CONTAMINATION.
MATERIAL HAS BEEN HEATED TO A MINIMUM OF 1900 DEG. F AND IS SUBSEQUENTLY COOLED RAPIDLY TO PREVENT CARBIDE PRECIPITATION.

Chemical Analysis

C	MN	P	S	SI	CR	NI	MO	CU	CO	N2
.045	1.59	.02	.0010	.30	18.05	8.14	.05	.14	0	.05

Physical Analysis

	YIELD		TENSILE		OTHER	
Hardness	PSI	MPA	PSI	MPA	Percent EL	Percent RA
RB 81.	42770	0	95870	0	62.	68.

THE CHEMICAL ANALYSES ARE CORRECT AS CONTAINED IN OUR CORPORATE RECORDS.
PHYSICAL PROPERTIES ARE DETERMINED WHILE MATERIAL IS IN STRIP FORM.
Melted & Manufactured in the USA FAR BAA complies, DFARS BAA complies, FAR TAA complies

ALRO STEEL/METAL



RT05782362

CERTIFIED BY:

Jerry Cripe

1185 WIN DR, BETHLEHEM, PA., 18017 - (610) 865-5337

FAX NUMBER: 610-865-4073

ALRO STEEL CORP
INDIANAPOLIS

NOV 03 2009

RECEIVED
SUBJECT TO COUNT INSP

24

CMTR SEARCH
RESULTS -
ICMTR.COM
Heat# 482863

FELKER
BROS. CORP.



FELKER BROTHERS
CORPORATION
22 NORTH CHESTNUT AVE
MARSHFIELD, WI. USA
54449
(800) 826-2304

REPORT
DATE: 4/29/2009

N/NO

CUSTOMER NAME: FELKER BROTHERS CORPORATION,
MARSHFIELD, WI

CERTIFIED DATE: 1/14/2009

PO LINE NUMBER: AP1157

PRODUCT

PART DESCRIPTION PIPE A312-304L 24 SCH10S
PRIMARY SPECIFICATION ASTM A312 08
GRADE TP304/TP304L
OTHER SPECIFICATIONS ASME SA312 01 NACE MRO175

CHEMICAL COMPOSITION

	Test A
CARBON	0.018
CHROMIUM	18.200
COPPER	0.260
MANGANESE	1.610
MOLYBDENUM	0.420
NICKEL	8.120
NITROGEN	0.070
PHOSPHORUS	0.027
SILICON	0.330
SULFUR	0.001

MECHANICAL PROPERTIES

ELONGATION-TRANS	2 IN	52
HARDNESS TEST	RB	86
TENSILE STRENGTH	PSI	91000
YIELD STRENGTH	PSI	53000

MANUFACTURER STEPS

* COUNTRY OF MELT IS	SWEDEN
* MANUFACTURED IN USA	
* PED 97/23/EC ANNEX1, PARA 4.3	
* EN764-5	
BEND/REVERSE BEND TEST	PASS
CORROSION TEST	PASS
DIMENSIONAL/VISUAL	PASS
EDDY CURRENT - WELD - E426	PASS
ETCHING TEST	PASS
HYDROSTATIC PRESSURE TEST	PSI 00300
PICKLING/PASSIVATION	YES

COMMENTS

TP304/TP304L DUAL CERT, WELDED
DIN 50049 3.1 / EN 10204 3.1
FELKER BROTHERS CORP DOES NOT USE MERCURY IN THE PRODUCTION NOR THE TESTING OF ITS PRODUCTS.
SOLUTION ANNEALED AT 1900 F

CERTIFICATION

IT IS CERTIFIED THAT ALL FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
WE CERTIFY THAT THESE PRODUCTS CONFORM TO SPECIFICATIONS LISTED ABOVE.
ISO 9001 CERTIFIED.

SCOTT MARTINEK
QUALITY MANAGER



東豐工業股份有限公司
TUNG FONG INDUSTRIAL CO., INC.

Tel: +63-46-4371036,37
+63-46-9710301
Fax: +63-46-4371038
+63-46-9710302

Phase III, Lot 10 and 12, Block 19,
Philippine Economic Zone Authority,
Rosario, Cavite, Philippines

Order No.: 98692
Ref. No.: T08-S19-PI01
Cert. No.: 101460-F
Date: 2009/05/08

Mill Test Certificate

1. Commodity: STAINLESS STEEL B.W. PIPE FITTINGS
2. Purchaser: SILBO INDUSTRIES, INC.
3. Material: ASTM A240 STAINLESS STEEL PLATES
4. Specification: ASTM/ASME A/SA403WP-2003 ANSI B16.9-2007 ANSI B16.25 WP304/304L-S

Item No.	Order Size				Description of Test			Pcs	Heat No.	Pipe Heat No.
					Surface & Dimension	Hydrostatic	Flattening			
30.	Cap	wp-s	304/304L	sch10s	1"	Good	N/A	30	T36378	T36378
31.	Cap	wp-s	304/304L	sch10s	1-1/2"	Good	N/A	75	T36378	T36378
32.	Cap	wp-s	304/304L	sch10s	2"	Good	N/A	250	T36378	T36378
33.	Cap	wp-s	304/304L	sch10s	2-1/2"	Good	N/A	30	139308	139308
34.	Cap	wp-s	304/304L	sch10s	3"	Good	N/A	200	139308	139308
35.	Cap	wp-s	304/304L	sch10s	5"	Good	N/A	50	YU154719	YU154719
36.	Cap	wp-s	304/304L	sch10s	6"	Good	N/A	100	YU154719	YU154719

Item No.	Mechanical (Physical) Property					Chemical Property						
	Yield Point	Tensile Strength	Hardness	Elongation		C	Mn	P	S	Si	Ni	Cr
	MPa	MPa	HRB	%		% (x1000)	% (x100)	% (x1000)	% (x1000)	% (x100)	%	%
30.	288.0	599.0	67.9	58.5		21	177	30	3	42	8.20	18.30
31.	288.0	599.0	67.9	58.5		21	177	30	3	42	8.20	18.30
32.	288.0	599.0	67.9	58.5		21	177	30	3	42	8.20	18.30
33.	289.0	601.0	65.0	54.0		24	125	29	2	40	8.12	18.60
34.	289.0	601.0	65.0	54.0		24	125	29	2	40	8.12	18.60
35.	280.7	601.3	81.0	49.0		17	144	22	5	41	8.25	18.17
36.	280.7	601.3	81.0	49.0		17	144	22	5	41	8.25	18.17
	205.0	515.0	90.0	40.0		30	200	45	30	100	8.00	18.00
	Min	Min	Max	Min		Max	Max	Max	Max	Max	10.00	20.00

THIS IS TO CERTIFY THAT ABOVE PRODUCTS ARE IN CONFORMITY WITH MECHANICAL(PHYSICAL) AND CHEMICAL PROPERTY INDICATED ABOVE. THE FITTINGS CONFORM IN EVERY WAY TO ASTM/ASME A/SA403 2003 WP304/304L AND TO ANSI B16.9-2007 ANSI B16.25 SPECIFICATION. HEAT TREATMENT AT 1050 DEGREE CENTIGRADE AND WATER QUENCHED. ALL GRADES OF THE MATERIAL HAS BEEN FURTHER VERIFIED TO BE MERCURY FREE AND NO WELD REPAIRS WERE PERFORMED. HARDNESS TO NACE MRO175-2003 AND NACE MRO103-2003 INTERCRYSTALLINE CORROSION ACCORDING TO ASTM/TYP E. CERTIFIED ACCORDING TO EN10204/3.1.B. PMI TESTED. S3460E TUNG FONG HAS ESTABLISHED A QMS ACCORDING TO ISO 9001, CERTIFIED BY TUV CERT.(01-100-089316) WITH PARTICULAR MATERIAL APPRAISAL PER BVQI CERT. (CE-PED-PMA-TF1001-08-TWN). COUNTRY OF ORIGIN ON ALL PIPES USED WITH HEAT NUMBERS AS INDICATED ABOVE IS TAIWAN.

TUNG FONG INDUSTRIAL CO., INC.

ORIGINAL

N/NO

Chief of Inspection Dept.

26



SHUANG LI (GROUP) CO., LTD
MILL TEST CERTIFICATE
(ACCORDING TO EN 10204 3.1B)



ORDER NUMBER: 96377A
SZ690E
Date: 2008/02/12

STAINLESS STEEL BUTT WELD FITTINGS CONFORMING WITH SA 403 WP-WASTM A403-008 T304/304L OR T316/316L DIMENSIONAL TOLERANCES TO H16.9

STAINLESS STEEL BUT WELD FITTINGS CONFORMING WITH SA 403 W/ W/STAINLESS STEEL																								
Order No.	Item No.	Material	Description	Size	Qty	Heat No	CHEMICAL COMPOSITION(%)										Mechanical Properties			Visual Inspection	Dimension Inspection	Heat Treatment	Hardness HB	Intergranular Corrosion
							C	Si	Mn	P	S	Ni	Cr	Mo	Ti	Tensile Strength MPa	Yield Point MPa	Elongation %						
	1	316L-W	SCH30S CON RED	2-1/2"X2"	20	BC060396	0.023	0.47	1.06	0.021	0.008	10.16	16.24	2.08		565	265	54	GOOD	GOOD	GOOD	GOOD		
	2	304L-WX	SCH30S RED TEE	10"X3"	6	BC07406	0.023	0.47	1.25	0.023	0.007	9.23	18.18			555	270	43	GOOD	GOOD	GOOD	GOOD		
	3	304L-WX	SCH30S RED TEE	10"X4"	10	BC07406	0.023	0.47	1.25	0.023	0.007	8.23	18.18			555	270	43	GOOD	GOOD	GOOD	GOOD		
	4	304L-WX	SCH30S CAP	10"	75	BB070055	0.022	0.46	1.21	0.020	0.007	8.21	18.08			560	255	51	GOOD	GOOD	GOOD	GOOD		
	5	304L-WX	SCH30S CAP	12"	75	BB070055	0.022	0.46	1.21	0.020	0.007	8.21	18.08			560	255	51	GOOD	GOOD	GOOD	GOOD		
	6	316L-WX	SCH30S RED TEE	12"X6"	10	BC07493	0.022	0.45	1.08	0.025	0.008	10.15	16.24	2.07		560	285	48	GOOD	GOOD	GOOD	GOOD		
	7	316L	SCH30S CAP	10"	100	BB070038	0.021	0.45	1.08	0.021	0.008	10.15	16.21	2.06		575	260	54	GOOD	GOOD	GOOD	GOOD		
	8	316L	SCH30S CAP	12"	50	BB070038	0.021	0.45	1.08	0.021	0.008	10.15	16.21	2.06		575	260	54	GOOD	GOOD	GOOD	GOOD		
	9	304L-W	SCH30S L.R. 90 ELBOW	8"	50	BC07161	0.021	0.45	1.22	0.023	0.009	8.16	18.17			560	255	61	GOOD	GOOD	GOOD	GOOD		
	10	304L-WX	SCH30S L.R. 90 ELBOW	10"	30	BC07527	0.023	0.46	1.07	0.022	0.007	8.16	18.24			575	260	51	GOOD	GOOD	GOOD	GOOD		
	11	304L-WX	SCH30S L.R. 90 ELBOW	12"	20	BC07528	0.022	0.48	1.21	0.023	0.008	8.16	18.21			565	270	48	GOOD	GOOD	GOOD	GOOD		
	12	304L-W	SCH30S L.R. 45 ELBOW	8"	10	BC07161	0.021	0.45	1.22	0.023	0.009	8.16	18.17			560	255	61	GOOD	GOOD	GOOD	GOOD		
	13	304L-WX	SCH30S L.R. 45 ELBOW	10"	15	BC07527	0.023	0.46	1.07	0.022	0.007	8.16	18.24			575	260	51	GOOD	GOOD	GOOD	GOOD		
	14	304L-W	SCH30S TEE	8"	10	BC07161	0.021	0.45	1.22	0.023	0.009	8.16	18.17			560	255	61	GOOD	GOOD	GOOD	GOOD		
	15	304L	SCH30S CAP	8"	50	BB070052	0.019	0.56	1.28	0.021	0.009	8.17	18.33			575	260	59	GOOD	GOOD	GOOD	GOOD		
	16	304L	SCH30S CAP	10"	20	BB070031	0.018	0.46	1.47	0.021	0.009	8.26	18.26			580	270	49	GOOD	GOOD	GOOD	GOOD		
	17	316L-WX	SCH30S L.R. 90 ELBOW	10"	6	BC06033	0.022	0.45	1.08	0.022	0.008	10.21	16.24	2.07		585	265	48	GOOD	GOOD	GOOD	GOOD		
	18	316L-WX	SCH30S L.R. 90 ELBOW	12"	6	BC07529	0.021	0.47	1.24	0.021	0.007	10.24	16.18	2.06		575	255	47	GOOD	GOOD	GOOD	GOOD		
	19	316L	SCH30S CAP	8"	20	BB070056	0.022	0.42	1.08	0.022	0.008	10.17	16.24	2.08		565	260	51	GOOD	GOOD	GOOD	GOOD		
	20	316L	SCH30S CAP	10"	13	BB070042	0.019	0.49	1.38	0.024	0.009	10.56	16.33	2.13		575	290	55	GOOD	GOOD	GOOD	GOOD		
REMARKS	MATERIAL IS DUAL CERTIFIED. MANUFACTURED TO ASA 403 WP/WPWX. WP/WX MATERIAL WAS X-RAYED. MANUFACTURER IS CERTIFIED ISO9001-2000. MATERIAL IS NACE MRD-175 COMPLIANT.																							
MATERIAL IS NACE MR0103-2003 COMPLIANT. MATERIAL IS MANUFACTURED MERCURY FREE AND FREE FROM MERCURY CONTAMINATION.																								
MATERIAL IS EN10204-3.1B COMPLIANT. MATERIAL IS PED 9723/EC CERTIFIED.																								

REMARKS: MATERIAL IS DUAL CERTIFIED. MANUFACTURED TO ASA 403 WP-WASTM A403-008 T304/304L OR T316/316L DIMENSIONAL TOLERANCES TO H16.9. MATERIAL IS NACE MR0103-2003 COMPLIANT. MATERIAL IS MANUFACTURED MERCURY FREE AND FREE FROM MERCURY CONTAMINATION.

MATERIAL IS EN10204-3.1B COMPLIANT. MATERIAL IS PED 9723/EC CERTIFIED.

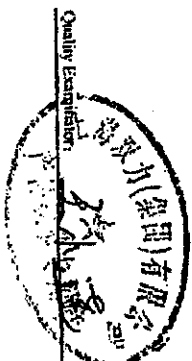
SHANGHAI SHUANG LI (GROUP) CO., LTD.

ADD: NO.1566, TIANWEI ROAD, JINSHAN

DISTRICT SHANGHAI, CHINA

Tel: 86-21-67256666-8111 Tel: 67256669

Fax: 86-21-67256669





CERTIFIED MATERIAL REPORT

FELKER BROTHERS CORPORATION
22 NORTH CHESTNUT AVE
MARSHFIELD, WI USA 54449
(800) 826-2304

Heat# 391025

CERTIFIED DATE: 10/13/2009

PRODUCT

Part Description	PIPE A312-304L 3 SCH10S		
Primary Specification	ASTM A312 08		
Grade	TP304/TP304L		
Other Specifications	ASME SA312 01	MIL-P-24691 / 3	NACE MRO 103
	NACE MRO 175		

CHEMICAL COMPOSITION

Carbon	.023
Chromium	18.030
Copper	.390
Manganese	1.350
Molybdenum	.240
Nickel	8.110
Nitrogen	.040
Phosphorus	.028
Silicon	.450
Sulfur	.013

MECHANICAL PROPERTIES

Elongation	2IN	63.0
Hardness	RB	79
Tensile	PSI	91100
Yield	PSI	35000

MANUFACTURER STEPS

Anneal Temperature	F	1900
Bend / Reverse Bend Test		Pass
Corrosion Test A262 Practice E		Pass
Dimensional / Visual		Pass
Eddy Current - Weld - E426		Pass
Eddy Current - Full Body - E426		Pass
Etching Test - Weld		Pass
Pickling / Passivation ASTM A380		Yes

COMMENTS

Country of melt is UNITED STATES OF AMERICA
Manufactured in USA
TP304/TP304L Dual Cert, Welded
Felker Brothers does not use mercury in the production nor the testing of its products

CERTIFICATION

It is certified that all figures are correct as contained in the records of the company.
We certify that these products conform to specifications listed above.
ISO 9001 Certified
DIN 50049 3.1/EN 10204 3.1
FAR BAA Complies
DFARS BAA Complies
FAR TAA Complies

Scott Martinek
Quality Manager

PELKER BROTHERS CORPORATION

ISO 9001 CERTIFIED
12 North Chestnut Avenue - Marshfield, Wisconsin 54449
Telephone (715) 384-3121 - Fax (715) 387-6837

MATERIAL TEST REPORT Inspection Certificate

See Additional Tests for Dual Certification

ROBERT-JAMES SALES, INC.
PO BOX 7929
BUFFALO
NY 142257939

ROBERT-JAMES SALES, INC.
P 2586 WALDEN AVE
T O BUFFALO
NY 14225

PAGE NO.	1
ORDER NO.	244832
CUST. PO. NO.	A01162
DATE SHIPPED	7/09/08

LINE #	DESCRIPTION	HEAT NUMBER	CARBON	MANG.	PHOS.	SULFUR	SILICON	CHROMIUM	NICKEL	NITROGEN	MOLY	COPPER
5	PIPE A312-304L 10 SCH5S	371714	.023	1.36	.029	.013	.54	18.13	8.17	.04	.25	.27
5	PIPE A312-304L 10 SCH5S	471243	.022	1.40	.026	.010	.45	18.13	8.12	.04	.22	.21
7	PIPE A312-304L 12 SCH10S	280267	.023	1.40	.028	.013	.45	18.15	8.11	.04	.36	.36
7	PIPE A312-304L 12 SCH10S	280463	.022	1.36	.025	.011	.46	18.16	8.16	.04	.29	.46
11	PIPE A312-304L 20 SCH10S	712061	.020	1.48	.028	.003	.44	18.11	8.04	.07	.05	.07
11	PIPE A312-304L 20 SCH10S	717062	.026	1.46	.029	.007	.43	18.38	8.28	.05	.04	.11
14	PIPE A312-316L 18 SCH10S	3JH4	.023	1.62	.031	.001	.38	16.69	10.30	.04	.2.11	.47
15	PIPE A312-316L 20 SCH10S	715133	.024	1.37	.032	.007	.36	16.93	10.05	.03	.2.06	

LINE #	HARDNESS	YIELD STRENGTH PSI	TENSILE STRENGTH PSI	ELONGATION %	ADDITIONAL TESTS
5	R5 RB	45100	99400	2	ABCEDEFGHIJLARUV
5	R5 RB	45000	95000	2	ABCEDEFGHIJLARUV
7	R5 RB	48900	95000	2	ABCEDEFGHIJLARUV
7	R5 RB	35800	85700	2	ABCEDEFGHIJLARUV
11	R2 RB	45000	88000	2	ABCEDEFGHIJLARUV
11	R2 RB	44000	91000	2	ABCEDEFGHIJLARUV
14	R6 RB	46840	91430	2	ABCEDEFGHIJLARUV
15	R3 RB	48000	88000	2	ABCEDEFGHIJLARUV

ASTM Specification Revision Levels

A778 = 01
A774 = 06
A312 = 07
A403 = 07
A269 = 07
A249 = 07

Pelker Brothers Corp. does not use mercury in the production nor in the testing of its products.

It is certified that all figures are correct as contained in the records of the company.

Additional Tests:

- A. Solution Annealed 1900°F
- B. Tension Test
- C. Bend Test/Rev. Bend Test
- D. Hydrostatic Test
- E. Pickle/Passivated A380
- F. Ekt - (Weid) E426
- G. Etching (Weid)
- H. Dimensional
- I. Visual
- J. 304/304L Dual Certification
- K. 316/316L Dual Certification
- L. ASTM A 312/ASME SA 312
- M. Eddy Current - (Full Body) E426
- N. Flange Test
- O. Flattening/Rev. Flattening Test
- P. SA403
- Q. Corrosion - ASTM - A262 - Pass
- R. DIN 50049 3.1 EN 10204 3.1
- S. 100% Radiographic Exam SA/A312 SS
- T. 100% Radiographic Exam
- U. NACE MRO175
- V. PED 97/23/EC Annex1, Para 4.3

Scott Martinek - Quality Manager



GKN SINTER METALS

(2) Eingangs- und Bearbeitungsvermerke/Customer remarks

Lieferschein Advice Note

Seite -1-

(3) Nr./No.
113190

(4) Versanddatum/Shipping date
25.01.2010

(5) Lieferanten-Nr./Supplier's Code

(8) Rechnung/Invoice-No.
0

(9) Datum/Date
25.01.2010

Kunden-Nr./Customer's No.
147008

Bereich
130 90 99

EDEN CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 USA U S A	Ship to: EDEN CRYOGENICS 8445 RAUSCH DRIVE PLAIN CITY, OH 43064 USA (614-873-3949) U S A
--	---

(10) Ihre Zeichen/Your ref.	(11) Bestellung Nr., Datum/Your Order-No., Date BC-3279 dated 10-Dec-2009	(12) Unsere Abt./Our dept. Katrin Vaupel 609-61	(13) Hausruf	(14) Unsere Auftrags-Nr./Our Ref-No. 317725
-----------------------------	--	--	--------------	--

(15) Zusatzdat. des Bestellers/Add.data	(16) Lieferwerk/Supplier	(17) Versandort/-beholdnis/Place of Shipment 42477 Radevormwald
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(19) Versandart/Type of delivery	frei (20) unfrei paid unpaid	(21) Verpackungsart/Packing *	(22) Versandzeichen/Marks and Nos
----------------------------------	---------------------------------	-------------------------------	-----------------------------------

Frachtbasis/Terms of delivery DDP	(23) brutto/gross - Gesamtgewicht/Weight - (24) netto/net (in kg)
--------------------------------------	---

(25) Versandanschrift (Warenempfänger)/Ship to address	(26) Abladestelle Unloading location
--	---

(27) Pos.	(28) Sachnummer Customer Part-No.	(29) Bezeichnung der Lieferung (Leistung)/Delivery description (21) Verpackungsart (Einzelheiten)/Packing details and Tag-No. *	(30) Menge Quantity	(31) Einheit Unit	Nachlieferung/ Back Order Menge Quantity
-----------	--------------------------------------	--	------------------------	----------------------	--

10	BC-02128-0057 3398050551503000	Ø 314.7/89x10mm SIKA-R 30 Sintered metal filters made of stainless steel AISI 316 L Diameter machined to size, with Hole acc. to GKN-Dwg, dated on 04.11.09 + Certificate 2.1	3,00	st	0
20	BC-02128-0058 3398050551503001	Ø 314.7x10mm SIKA-R 30 Sintered metal filters made of stainless steel AISI 316 L Diameter machined to size + Certificate 2.1	3,00	st	0
30	500	Transport charges in USA	1,00	st	0

County of Origin: Fed. Rep. of Germany
Weights: net 9.723+10.620=20.343 kg / gross 26 kg
Customs Tariff No.: 8421.99.00.40 (US-Tariff-No.)
Packing: 1 plywood-case, 52x36x22 cm
Delivery: Federal Express, 25-Jan-10
Marks: FedEx Tracking No. 6210 9358 4899

30

EXPECT MORE

(42) Eingangsvermerke Receiver's remarks	(43) Mengenprüfung Quantity check	(44) Güteprüfung/Prüfbericht Quantity check	(45) Empfänger Receiver	(46) Rechnungsprüfung Invoice check
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42477 Radevormwald

WERKSCHESCHINIGUNG EN 10204-2.1
CERTIFICATE OF COMPLIANCE WITH THE ORDER EN 10204-2.1
Serial No.: 317725_10

zu Lieferanzeige Nr. / to Delivery Note No. :

Besteller / Purchaser : Eden Cryogenics
Bestell-Nr. / Purchaser no. : BC-3279
Artikel-Nr. / Part no. : 3398050551503000-Z
Abmessung / Dimension : $\varnothing 314,4/89 \times 10 \text{ mm}$
Werkstoff-Bezeichnung / Compound no. : 1.4404
Norm / Spezifikation :
Herstellerbezeichnung des WS / Supplier's compound : Filters of sintered metal
Liefermenge / Quantity : 3 pcs.
Auftrags-Nr. / Order no. : 317725-10
Lieferdatum / Delivery date : 22.01.10
Batch-Nr. / Batch no. :
Herstellerzeitraum / Prod. date :
Prüfberichts-Nr. / Inspection-Report-no. : A317725_10
Kundenidentifikationsnummer / Customer identnr. : BC-02128-0057

Eigenschaft characteristic	Einheit unit	Prüfverf. inspect.	M.Type dtype	Nennm./STP nom/s.size	OT ut	UT lt	Min./n.i.O min./n.con	Max./i.O max./con.	M.Wert/Erg. mean/result
Material No.: 1.4404		F1	A	1			0	1	1.0
Material: X2CrNiMo17-12-2		F1	A	1			0	1	1.0
GKN-Quality: SIKAR 30		F1	A	1			0	1	1.0

Wir bestätigen mit den oben aufgeführten Prüfergebnissen aus der laufenden betrieblichen Prüfung von Erzeugnissen aus dem gleichen Werkstoff und der gleichen Herstellart wie die Lieferung selbst, daß die Lieferung den Vereinbarungen bei der Bestellannahme entspricht.

We confirm with above mentioned inspection results on the regular internal inspections of products made of the same compound and production method as the delivery, that the delivery is in accordance with the agreements at the order acceptance.

42477 Radevormwald, 22.01.10

(Ort und Datum)

GKN Sinter Metals Filters GmbH
Radevormwald

A. Rainer Prescha

(Quality assurance)

30

42477 Radevormwald

WERKSCHESCHENIGUNG EN 10204-2.1
CERTIFICATE OF COMPLIANCE WITH THE ORDER EN 10204-2.1
Serial No.: 317725_20

zu Lieferanzeige Nr. / to Delivery Note No. :

Besteller / Purchaser : Eden Cryogenics
Bestell-Nr. / Purchaser no. : BC-3279
Artikel-Nr. / Part no. : 3398050551503001-2
Abmessung / Dimension : $\varnothing 314,4 \times 10 \text{ mm}$
Werkstoff-Bezeichnung / Compound no. : 1.4404
Norm / Spezifikation :
Herstellerbezeichnung des WS / Supplier's compound : Filters of sintered metal
Liefermenge / Quantity : 3 pcs.
Auftrags-Nr. / Order no. : 317725-20
Lieferdatum / Delivery date : 22.01.10
Batch-Nr. / Batch no. :
Herstellerzeitraum / Prod. date :
Prüfberichts-Nr. / Inspection-Report-no. : A317725_20
Kundenidentifikationsnummer / Customer identnr. : BC-02128-0058

Eigenschaft characteristic	Einheit unit	Prüfverf. inspect.	M.Typ dtype	Nennm./STP nom/s.size	OT ut	UT lt	Min./n.i.O min./n.con	Max./i.O max./con.	M.Wert/Erg. mean/result
Material No.: 1.4404		Fl	A	1			0	1	i.O
Material: X2CrNiMo17-12-2		Fl	A	1			0	1	i.O
GKN-Quality: SIKA-R 30		Fl	A	1			0	1	i.O

Wir bestätigen mit den oben aufgeführten Prüfergebnissen aus der laufenden betrieblichen Prüfung von Erzeugnissen aus dem gleichen Werkstoff und der gleichen Herstellart wie die Lieferung selbst, daß die Lieferung den Vereinbarungen bei der Bestellannahme entspricht.

We confirm with above mentioned inspection results on the regular internal inspections of products made of the same compound and production method as the delivery, that the delivery is in accordance with the agreements at the order acceptance.

42477 Radevormwald, 22.01.10

(Ort und Datum)

GKN Sinter Metals Filters GmbH
Radevormwald

1.A. Rainer Prescha

(Quality assurance)

30



WALSIN LIHWA CORPORATION YENSHUI PLANT

ISO-9001, ISO-14001 CERTIFIED

3-10, SHI JOU LIAU, CHIN SHUEI LI,
YENSHUI CHEN, TAINAN HSIEN, TAIWAN R.O.C.

MILL TEST / INSPECTION CERTIFICATE

Tel: (06)5209111 Fax: (06)53376

Customer								Date	2009/08/28	File	2009090829					
Steel Grade		ANSI	304L	Commodity		Stainless Steel Bar		Order No.	323368	P.O.NO.	L26105					
Item	Bar No.	Heat No.	Shape	Size	Quantity(Pcs)	Weight (LBS)	Condition	Workmanship								
1	WL9033002	9C730	H	1-1/8"	53	2380	CD	Length: 4150mm, Tolerance: A484.								
2	WL9033003	9C730	H	1-3/8"	23	1556	CD	Material is free from mercury contamination								
								No welding repaired								
								Solution treatment at 1040°C : 1-2 hour : water quenched								
								Grain size test by E112 : fine (5-8)								
								Macro and micro structure : ok								
								Intergranular corrosion test by ASTM A262 Practice E : OK								
								Country of melted & Manufactured: Taiwan								
Chemical Composition (WT%)																
Kind of Test	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	N	Co	Hardness (HB)	Tensile Strength (KSI)	Yield Strength (KSI)	Elongation (%)	Reduction of Area (%)
Spec.	0.03	1.00	2.00	0.045	0.030	8.00	18.00			0.10		MIN				
	MAX	MAX	MAX	MAX	MAX	10.50	20.00			MAX		MAX				
1	0.015	0.345	1.713	0.031	0.027	8.033	18.216	0.202		0.083		183	98.7	69.7	56	77
2	0.015	0.345	1.713	0.031	0.027	8.033	18.216	0.202		0.083		192	94.5	73.4	55	77
Condition:			Invoice No. WL9033 L/C No.						Shape:		Here we certify that the material described herein has been manufactured and tested with satisfactory results in accordance with the requirement of the above material specification.					
S-Solution Treated A-Annealed			Acc. To ASTM A176-06 cond.A, A479-04 cond.A.						R : Round							
HR-Hot Rolled P-Polished			A 484/A484M, A182-04a, A193-04a B8 Class						H : Hexagonal							
CD-Cold Drawn PL-Peeling			A320-01 B8 Class, A262 Practice E, EN10204 3.1.3						S : Square							
ST-Smooth Turned			ASME SA479-E01 cond.A, SA182E01 A03.						SR : Square-Round							
CG-Centerless Grinding			SA193-E01 A02 B8 Class, SA320-01a B8 Class						E : Ellipse							
			AMS QQS-763P, AMS 5639H, 5647H, UNS S30400, S30403						FB : Rectangular							
MANAGER OF QUALITY ASSURANCE DEPARTMENT: M.L.Chiang																

Hot Code # L6

MILL TEST REPORT

TA CHEN INTERNATIONAL CORPORATION

www.tachen.com

This MTR contains 1 page (Page: 1)

MTR#: TCFB05071 Customer#: ALR2AC PO#: 7028883 SO#: CP4414

Item#: G4L00180100 Bundle#: JG0198-034 Heat#: 252208

Item#: G4L00180100 Bundle#: JG0198-035 Heat#: 252208 Item#: G4L00180100

Bundle#: JG0198-041 Heat#: 158654

Item No.	Tensile Test				Hardness Test	Bend Test	Heat Treatment Temp. of F.	Dimension And Surface Condition
	0.2% Yield Strength PSI	Tensile Strength PSI	Elongation %	Reduction of Area %				
13	43500	67400	52.00	62.00	88.00	OK	1550	OK
14	42500	67400	52.00	62.00	88.00	OK	1550	OK
15	39500	69100	54.00	64.00	82.00	OK	1550	OK
16	44000	91200	50.00	60.00	85.00	OK	1550	OK
17	44000	91200	50.00	60.00	85.00	OK	1550	OK
18	43800	89000	53.00	63.00	85.00	OK	1550	OK

We hereby certify the above statement to be true and correct every detail
TA CHEN has established a QMS according to ISO 9001, which is certified by LRQA (cert. no. TYN036325)

Item No.	Case No. (Crate No.)	Heat No.	Supplier	Size	Quantity Weight Pcs Kgs	Chemical Composition in %									
						C	Si	Mn	P	S	Ni	Cr	Mo	N	
13	007,000,000,000	252208	YU800	.187 X 1.500 X 144 304/304L	955	0.021	0.400	1.390	0.007	0.004	0.030	18.13	-	0.039	
14	000,001,002,003,004	252208	YU800	.187 X 2.000 X 144 304/304L	1173	0.021	0.400	1.390	0.007	0.004	0.030	18.13	-	0.039	
15	000,001,002,003,004	158654	YU800	.250 X 1.000 X 144 304/304L	924	0.017	0.390	1.590	0.003	0.005	0.110	18.11	-	0.040	
16	000,001,002,003,004	252208	YU800	.250 X 1.000 X 144 304/304L	1481	0.029	0.520	1.400	0.003	0.002	0.160	18.21	-	0.035	
17	000,001,002,003,004	252208	YU800	.250 X 1.250 X 144 304/304L	1124	0.028	0.620	1.400	0.003	0.002	0.160	18.21	-	0.035	
18	000,001,002,003,004	158277	YU800	.250 X 1.500 X 144 304/304L	1630	0.023	0.440	1.450	0.002	0.004	0.090	18.19	-	0.042	
Total					0	7348									

ALRO STEELMETAL

RT05791712

Remarks

1. NO WELD REPAIR PERFORMED
2. FREE OF MERCURY CONTAMINATION
3. ASTM A262-01 PRACTICE OK
4. MECHANICAL PROPERTIES ARE MEASURED FROM SHEET COIL BEFORE CUTTING.
5. NACE MR0175-07
6. ALL RAW MATERIALS HAS BEEN ANNEALED BEFORE CUTTING AND DELIVERED ROLLING

Signatures

ALRO STEEL CORP.
INDIANAPOLIS

Manager of Inspection Section/Guang Yang

SEP 24 2009

SUBJECT TO COUNT INSPECTION

file://C:\TEMP\VictorKluth

TCFB05071

Mill Test Report

Commodity : STAINLESS STEEL PLATE CUT STRIP

Customer : TA CHEN INTERNATIONAL, INC.

EN 10204-3.1
TA CHEN STAINLESS PIPE CO., LTD.
NO. 125 HSIUN-TIEN 2ND ST.,
JENG-TEH, TAINAN, TAIWAN
TEL: (06) 2797254 FAX: (06) 2701382
COUNTRY ORIGIN: TAIWAN

Specification

: ASTM A240-2007/A490-2006B, ASME SA240-2004/SA490-19
ASTM A276-01/ASTM A566-03 ChemMech. only
ASTM A479-01/ASME SA479-95 ChemMech. only
ASTM A494-01 ChemMech. only

Shipper : TA CHEN STAINLESS PIPE CO., LTD.

Destination : CHICAGO

Customer's PO# : L2657

Factory O/N : G4024728

Certificate NO : JG0198001

QCS-76

Date : 2009/7/31

INVOICE NO : G402800198

9/23/2009

32

McMASTER-CARR®

Aurora Industrial Parkway
Aurora OH 44202
995-5500
sales@mcmaster.com

Eden Cryogenics LLC
8445 Rausch Dr
Plain City OH 43064

Purchase Order
BC-3344

McMaster-Carr Number
5596337-01

Pay-

01/06/2010

A1

Line	Description	Ordered	Shipped		
1	33045T81 Type 304 Stainless Steel Eyebolt for Lifting, with Shoulder, 3/8"-16 Thread, 1300# Work Load Limit, 1-1/4" L Thread	9 Each	9	1 - 319 - 01 06 - 70 T81	9 EA 1
2	90298A597 18-8 Stainless Steel Shoulder Screw, 5/16" Shoulder Diameter, 3-1/2" Shoulder L, 1/4"-20 Thread	12 Each	7	1 - 552	2

Shipped separately from our Cleveland warehouse on 01/06

2	90298A597 18-8 Stainless Steel Shoulder Screw, 5/16" Shoulder Diameter, 3-1/2" Shoulder L, 1/4"-20 Thread	12 Each	5
3	9663K56 Type 302 Stainless Steel Continuous Length Compression Spring, 20" Length, .375" OD, .032" Wire Diameter	4 Packs	4
4	91187A548 ASTM A193 Grade B8 Stainless Steel Fully Threaded, Rod, 1/2"-13 Thread, 3' Length	5 Packs	5

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog.

Jason Wolfe

Jason Wolfe
Compliance Manager

Eden Cryogenics LLC

Assembly
Area

1

Cycle

45

Shelf

111

Documents

2

SS-R-0707

20

2 lb
2 line

EW1BSPA6
01/06/2010
14:03/14:15
277

0100451084636



McMASTER-CARR®

Industrial Parkway
OH 44202
5500
sales@mcmaster.com

Eden Cryogenics Llc
8445 Rausch Dr
Plain City OH 43064

Purchase Order
BC-3344

McMaster-Carr Number
5596337-02

Page 1 of 2

01/06/2010

Description		Ordered	Shipped			A86
90298A597	18-8 Stainless Steel Shoulder Screw, 5/16" Shoulder Diameter, 3-1/2" Shoulder L, 1/4"-20 Thread	12 Each	5	2 - 692 - 08	21 - 79 A597	5EA 2
9663K56	Type 302 Stainless Steel Continuous Length Compression Spring, 20" Length, .375" OD, .032" Wire Diameter, Packs of 1	4 Packs	4	3 - 512		3
91187A548	ASTM A193 Grade B8 Stainless Steel Fully Threaded, Rod, 1/2"-13 Thread, 3' Length, Packs of 1	5 Packs	5	6 - 49		4

ipped separately from our Chicago warehouse on 01/06

33045T81	Type 304 Stainless Steel Eyebolt for Lifting, with Shoulder, 3/8"-16 Thread, 1300# Work Load Limit, 1-1/4" L Thread	9 Each	9
CP 98A597	18-8 Stainless Steel Shoulder Screw, 5/16" Shoulder Diameter, 3-1/2" Shoulder L, 1/4"-20 Thread	12 Each	7

Eden Cryogenics Llc

Assembly
Area

36

Cycle

48

Shelf

603

Documents

3

9 lbs
3 lines

FW1WBP25
01/06/2010
14:03/14:32
033

0100651084643



v10.18.12 172 / 424

Purchase Order
BC-3344

Page 2 of 2

McMaster-Carr Number
5596337-02

01/06/2010

Corona Industrial Parkway
H 44202
J-500-5500
a.sales@mcmaster.com

Eden Cryogenics Llc
8445 Rausch Dr
Plain City OH 43064

ertificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog.



Jason Wolfe
Compliance Manager

McMASTER-CARR.

REC-11122

Purchase Order
BC-3364

Aurora Industrial Parkway
Aurora OH 44202
995-5500
es@mcmaster.com

Eden Cryogenics LLC
8445 Rausch Dr
Plain City OH 43064

McMaster-Carr Number
5817366-01

01/13/2010

Line	Description	Ordered	Shipped
1	4464K221 Type 304 Stainless Steel Thread Pipe Fitting, 1/8" Pipe Size, 5/8" OD, Half Coupling, 1000 PSI, 1/2" L	3 Each	3
2	8063K31 Brass Air Tank Valve, 1/8" NPT, 1-5/16" Overall Length	3 Each	3
3	5033K32 Extreme-Temperature Tubing Made with Teflon(r) PTFE, 3/16" ID, 5/16" OD, 1/16" Wall, Semi-Clear White	40 Feet	40
4	98390A461 Plain Steel Taper Pin, #9 X 6" L, .591" Large End Diameter, .466" Small End Diameter, Packs of 1	4 Packs	4

A84

2 - 266 - 03	05 - 41	K221	3 EA	1
2 - 314				2
2 - 23				3
3 - 326				4

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog.

Jason Wolfe

Jason Wolfe
Compliance Manager

Eden Cryogenics LLC

Assembly
Area

84

Cycle

22

Shelf

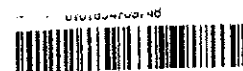
401

Documents

4

4
4 lb

FW1BSF
01/13/20
09:34/10
207





2023/10/11
P.O. Box 2649
Galveston, TX 77553
Galveston: 409.765.9003
Houston: 281.480.7764
1-800.231.9450
Fax: 409.765.7115

Delivery Ticket \ Packing

CUSTOMER - COPP

Page 1 of 1

Date Ordered 01/07/2010	Customer No 210428	Customer P.O. BC-3347	Customer Contact	Payment Terms Net 30
Shipped Date 01/07/2010	Ship Via UPS GROUND	FOB Warehouse	Freight Terms Prepaid and Add	Tracking BOL # 1216168
Customer Service Rep Jessica Bacon	Entered By Jessica Bacon	FCIS Ref	Status Complete	Sales Order - Shipment 813017-1

Ship From
Farmer's Copper Ltd.
1115 Brussels St.
San Antonio, TX 78219 United States

Sold To
EDEN CRYOGENICS, LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064 United States

Interim Destination

Ship To Destination
EDEN CRYOGENICS, LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064 United States

Line	Containers	Qty UOM	Item Number \ Description \ Specifications	Qty Ord UOM	Qty Shipped	Qty Bld	\$Per UOM	Additional Charges	Extended Amount
1	1 40951-042	2 PCS	R061015000T6---- 1-1/2" ROUND 6061-T6 ALUMINUM BAR PIECES = 2.0, LENGTH = 72.0, CUTTING-1 = Bar, TOLERANCE = CUT FOR SHIPPING, DOCS = CERTSHIP, PROTECTION = STD, THICKDIA = 1.5	1.000 Lot	1.000	0.000			
2	1 40973-028	1 PCS	R061025000T6---- 2-1/2" ROUND 6061-T6 ALUMINUM BAR ATTN: JOHN ADAIR PIECES = 1.0, LENGTH = 84.0, CUTTING-1 = Bar, TOLERANCE = +125 -0, DOCS = CERTSHIP, PROTECTION = STD, THICKDIA = 2.5	1.000 Each	1.000	0.000			

Aurora Industrial Parkway
Aurora OH 44202
955-5500
sales@mcmaster.com

Eden Cryogenics LLC
8445 Rausch Dr
Plain City OH 43064

McMaster-Carr Number
5618505-01

01/07/2010

Line	Description	Ordered	Shipped
1	92510A763 Aluminum Unthreaded Round Spacer, 1/2" OD, 5/16" Length, 1/4" Screw Size	360 Each	360
2	3335161 45 Degree Mirror for 20" Diameter Bore, Inspection BoreScope Your Part Number: RANDY BASHAM	Each	Each

A11

2 - 117 - 02	06 - 50	A763	360 EA	1
1 - 324				2

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog.

Jason Wolfe

Jason Wolfe
Compliance Manager

Eden Cryogenics LLC

Assembly
Area

11

Cycle

13

Shelf

115

Documents

2

2 lbs
2 lines

FW1BSP19
01/07/2010
07:45/08:12
494

010072050176





COLUMBUS FASTENERS CORP.

Date: April 26, 2010

Purchaser: Eden Cryogenics, LLC
8445 Rausch Drive
Plain City, Oh 43064

To Whom It May Concern:

It is hereby certified that all the articles in the quantities as called for in the Purchase Order # designated below and issued by you on the date listed below are in conformance with the requirements, specifications and drawings listed on that order. Additionally, articles called for in this Purchase Order are in conformance with applicable Industrial Fastener Institute specifications.

Purchase Order Numbers: BC-3765

Date of Purchase Order: 04/26/10

Columbus Fasteners Corp.

By: 

David J. Hill

1150 Chesapeake Ave.

Columbus, OH 43212

Phone 614-486-6670

Fax 614-486-2485

Pick List: 384541

Order Number: M485372

Created: 1/11/2010 6:51:0

ORDER INFORMATION

Delivery Address:

EDEN CRYOGENICS LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
UNITED STATES

Delivery Site:

Terms of Delivery:

Ship Via:

PO Number:

Route Id:

Forward Agent:

Label Note:

Our Reference:

MDC VACUUM PRODUCTS

COLLECT 28F3A6

UPS COLLECT

BC-3348

LINDA COOPER

614-873-3949 f 614-873-6925

Certificate of Conformance

This is to certify that the material referenced on the above PO and listed on the attached pick list were manufactured to the customer's requirements or to MDC's internal drawing and specifications.

Materials used in the production of this order are certified as new and not counterfeit. Any deviation to specifications has been authorized by the customer.

MDC Vacuum Products is an ISO 9001:2008 registered company. Key elements of our fully implemented Quality Management System include our Quality Manual, Quality Policy, Product Objectives, Process Measurements, Design Capability and Validation, detailed production Process Travelers, Corrective / Preventive Action System, Nonconforming Material System, Calibration, First Article / First Piece / CNC Program Qualification Process, Internal Audits, and Sub-Supplier Program.

Quality Management Contacts:

MDC, VPD, Hayward, CA (510) 265-3500

MDC, ISI, Sarasota, FL (941) 751-2880

MDC, SSD, San Jose, CA (408) 350-0244

Report:

Pick List for Customer Order

IFS Applications

ORDER INFORMATION

Delivery Address:

EDEN CRYOGENICS LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
UNITED STATES

Delivery Site:

Terms of Delivery:

Ship Via:

PO Number:

Route Id:

Forward Agent:

Label Note:

Our Reference:

MDC VACUUM PRODUCTS
COLLECT 28F3A6
UPS COLLECT
BC-3348

LINDA COOPER

614-873-3949 f 614-873-6925

Certificate of Conformance

This is to certify that the material referenced on the above PO and listed on the attached pick list were manufactured to the customer's requirements or to MDC's internal drawing and specifications.

Materials used in the production of this order are certified as new and not counterfeit. Any deviation to specifications has been authorized by the customer.

MDC Vacuum Products is an ISO 9001:2008 registered company. Key elements of our fully implemented Quality Management System include our Quality Manual, Quality Policy, Product Objectives, Process Measurements, Design Capability and Validation, detailed production Process Qualification Process, Internal Audits, and Sub-Supplier Program.

Quality Management Contacts:

MDC, VPD, Hayward, CA (510) 265-3500
MDC, ISI, Sarasota, FL (941) 751-2880
MDC, SSD, San Jose, CA (408) 350-0244

Pick List: 386747

Order Number: M485372

Created: 01/28/2004

ORDER INFORMATION

Delivery Address:

EDEN CRYOGENICS LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064
UNITED STATES

Delivery Site:

MDC VACUUM PRODUCTS

Terms of Delivery:

COLLECT 28F3A6

Ship Via:

UPS COLLECT

PO Number:

BC-3348

Route Id:

Forward Agent:

Label Note:

Our Reference:

LINDA COOPER

614-873-3949 F 614-873-6925

Certificate of Conformance

This is to certify that the material referenced on the above PO and listed on the attached pick list were manufactured to the customer's requirements or to MDC's internal drawing and specifications.

Materials used in the production of this order are certified as new and not counterfeit. Any deviation to specifications has been authorized by the customer.

MDC Vacuum Products is an ISO 9001:2008 registered company. Key elements of our fully implemented Quality Management System include our Quality Manual, Quality Policy, Product Objectives, Process Measurements, Design Capability and Validation, detailed production Process Travelers, Corrective / Preventive Action System, Nonconforming Material System, Calibration, First Article / First Piece / CNC Program Qualification Process, Internal Audits, and Sub-Supplier Program.

Quality Management Contacts:

MDC, VPD, Hayward, CA (510) 265-3500
MDC, ISI, Sarasota, FL (941) 751-2880
MDC, SSD, San Jose, CA (408) 350-0244

Report: Pick List for Customer Order

IFS Applications



Packing List

Date: 15-Jan-10

Customer No: S5691.01

Page: 1 of 1

Scioto Valve and Fitting Co.
100 Hoff Rd. Suite M
Westerville, OH 43082
(614) 212-7766
(614) 212-7767 fax
www.swagelok.com/scioto

Charleston Valve and Fitting Co.
P.O. Box 8656, 507 1st Ave.
South Charleston, W. Va. 25303
(304) 744-3461
(304) 744-1453 fax
www.swagelok.com/charleston

Bill To: EDEN CRYOGENICS, LLC
8445 RAUSCH DRIVE
ATTN: ACCOUNTS PAYABLE
PLAIN CITY, OH, 43064

Ship To: EDEN CRYOGENICS, LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH, 43064

PO Number: BC-3349

Order No: 0001076555

Order Date: 7-Jan-10

Entered By: Michael

Cust. Contact: A. DIMASSO

Proposal No: 053753

Shipment Method

UPS

<input checked="" type="checkbox"/>	Line	Description	Location	Qty Ordered	Qty Shipped	Qty B/O	Unit Price	Amount
053753	1	SS-16-VCR-1 Female VCR Nut, 1"		2	2	0		
CUSTOMER REQUIRES C OF C ON ALL ORDERS								
Order Picked By:			Order Shipped By:				Subtotal	
Customer Notified By:			Date:				Freight	
Items Received By:			Date:					

COMPLETE

All claims and shortages must be reported within 10 days after receipt of shipment.
Returns require prior authorization and are subject to a 20% restocking charge.
Factory special and custom configured items are non-cancelable and non-returnable.

swagelok

Packing List

Date: 12-Jan-10

Customer No: S5691.01

Page: 1 of 1

Swagelok Valve and Fitting Co.
1000 Hoff Rd. Suite M
Westerville, OH 43082
(614) 212-7766
(614) 212-7767 fax
www.swagelok.com/scioto

Charleston Valve and Fitting Co.
P.O. Box 8656, 507 1st Ave.
South Charleston, W. Va. 25303
(304) 744-3461
(304) 744-1453 fax
www.swagelok.com/charleston

Bill To: EDEN CRYOGENICS, LLC
8445 RAUSCH DRIVE
ATTN: ACCOUNTS PAYABLE
PLAIN CITY, OH 43064

Ship To: EDEN CRYOGENICS, LLC
8445 RAUSCH DRIVE
PLAIN CITY, OH 43064

PO Number: BC-3349

Order No: 0001076555

Order Date: 7-Jan-10

Entered By: Michael

Cust. Contact: A. DIMASSO

Proposal No: 053625

Shipment Method

UPS

✓	Line	Description	Location	Qty Ordered	Qty Shipped	Qty B/O	Unit Price	Amount
053625	1	SS-16-VCR-1 Female VCR Nut, 1"		7	5	2		
053625	2	SS-16-VCR-3 VCR Gland, 1" Tube SW		7	7	0		
053625	3	SS-16-VCR-4 Male VCR Nut, 1"		7	7	0		
053625	4	SS-16-VCR-2-VS Stainless Steel VCR Unpla		7	7	0		
CUSTOMER REQUIRES C OF C ON ALL ORDERS								

Order Picked By:

Order Shipped By:

Subtotal

Customer Notified By:

Date:

Freight

Ins Received By:

Date:

PARTIAL

All claims and shortages must be reported within 10 days after receipt of shipment.
Returns require prior authorization and are subject to a 20% restocking charge.
Factory special and custom configured items are non-cancelable and non-returnable.



Swagelok Company
29500 Solon Rd
Solon, OH 44139 U.S.A
440.349.5600
440.519.4997 fax

Certificate of Compliance (EN 10204-2.1)

Distributor	Customer	Customer PO#
Scioto Valve & Fitting Co. 200 Hoff Road Suite M Westerville, OH 43082	EDEN CRYOGENICS, LLC 8445 RAUSCH DRIVE PLAIN CITY, OH 43064	BC-3349

No. Part Number	Qty
1 SS-16-VCR-1	7
2 SS-16-VCR-4	7

Swagelok products referenced above are manufactured from material purchased and certified as being in accordance with the specification(s) listed below.

The material stipulations included in this certification do not include such components as snap rings, springs, balls, o-rings, gaskets, jam nuts, space collars, seals, locking dogs, lanyards, or sleeves.

Stainless steel material has passed the Intergranular Corrosion Test requirements of EN ISO 3651-2, Method A, and/or ASTM A-262 Practice A or E.

All parts were cleaned and packaged in accordance with Swagelok Specifications.

MATERIAL STANDARDS

Components	Material	Standards
Shaped Fittings	F316 Stainless Steel Forgings	ASTM A182, ASME SA182
Straight Fittings	316 Stainless Steel Bar	ASTM A276, ASTM A479, ASME SA479

The Swagelok® products specified above are certified for use in commercial-grade (non-Nuclear Safety Related) applications and were manufactured in accordance with Swagelok Company's Quality Assurance Manual (latest revision, revision H, dated December 10, 2007). Swagelok Company's Quality System is approved to ISO 9001 (BSI Certificate # FM01729).

Certifications Supervisor
Jonathan Seewald

Certificate of Compliance (EN 10204-2.1)

Distributor	Customer	Customer PO#
Scioto Valve & Fitting Co. 200 Hoff Road Suite M Westerville, OH 43082	EDEN CRYOGENICS, LLC 8445 RAUSCH DRIVE PLAIN CITY, OH 43064	BC-3349

No. Part Number	Qty
1 SS-16-VCR-CP	7

Information contained in the above customer address column (marked as "Customer") and area marked "Reference" (when applicable) of this certification are for reference purposes only. Swagelok Company makes no stipulations, nor takes responsibility, for the accuracy or reliability of such information.

Swagelok products referenced above are manufactured from material purchased and certified as being in accordance with the specification(s) listed below.

Swagelok products are manufactured under conditions which are free from mercury. No Mercury bearing components have been used in the products of your order and no Mercury bearing instruments or other equipment have been used in their manufacture, assembly, or testing in such a manner as might cause contamination.

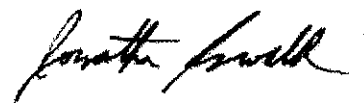
No asbestos or asbestos-containing components are used in Swagelok brand products.

All parts were cleaned and packaged in accordance with Swagelok Specifications.

MATERIAL STANDARDS

Components	Material	Standards
Body	316 Stainless Steel Bar	ASTM A276, ASTM A479, ASME SA479
VCR Nut	316 Stainless Steel Bar	ASTM A276, ASTM A479, ASME SA479

The Swagelok® products specified above are certified for use in commercial-grade (non-Nuclear Safety Related) applications and were manufactured in accordance with Swagelok Company's Quality Assurance Manual (latest revision, revision H, dated December 10, 2007). Swagelok Company's Quality System is approved to ISO 9001 (BSI Certificate # FM01729).



Certifications Supervisor
Jonathan Seewald



Swagelok Company
29500 Solon Rd
Solon, OH 44139 U.S.A
440.349.5600
440.519.4997 fax

Certificate of Compliance (EN 10204-2.1)

Distributor	Customer	Customer PO#
Scioto Valve & Fitting Co. 200 Hoff Road Suite M Westerville, OH 43082	EDEN CRYOGENICS, LLC 8445 RAUSCH DRIVE PLAIN CITY, OH 43064	BC-3349

No. Part Number	Qty
1 SS-16-VCR-3	7

Information contained in the above customer address column (marked as "Customer") and area marked "Reference" (when applicable) of this certification are for reference purposes only. Swagelok Company makes no stipulations, nor takes responsibility, for the accuracy or reliability of such information.

Swagelok products referenced above are manufactured from material purchased and certified as being in accordance with the specification(s) listed below.

Swagelok products are manufactured under conditions which are free from mercury. No Mercury bearing components have been used in the products of your order and no Mercury bearing instruments or other equipment have been used in their manufacture, assembly, or testing in such a manner as might cause contamination.

No asbestos or asbestos-containing components are used in Swagelok brand products.

Stainless steel material has passed the Intergranular Corrosion Test requirements of EN ISO 3651-2, Method A, and/or ASTM A-262 Practice A or E.

All parts were cleaned and packaged in accordance with Swagelok Specifications.

MATERIAL STANDARDS

Components	Material	Standards
Shaped Fittings	F316 Stainless Steel Forgings	ASTM A182, ASME SA182
Straight Fittings	316 Stainless Steel Bar	ASTM A276, ASTM A479, ASME SA479

The Swagelok® products specified above are certified for use in commercial-grade (non-Nuclear Safety Related) applications and were manufactured in accordance with Swagelok Company's Quality Assurance Manual (latest revision, revision H, dated December 10, 2007). Swagelok Company's Quality System is approved to ISO 9001 (BSI Certificate # FM01729).

Certifications Supervisor
Jonathan Seewald

PACKING LIST

ORDER NO.	123612
01055031	

S
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LO
D

EDEN CRYOGENICS, LLC.
8445 RAUSCH DRIVE
PLAIN CITY OH 43064

CUSTOMER NO.	PART NAME	QTY ORDERED	DATE ORDERED	DATE SHIPPED	DATE RECEIVED	QUANTITY TO BE ORDERED
EPCRY	SCOTT-EM	CJC/	david	NET 30		01/07/10
PURCHASE ORDER NO.	REFERENCE	DATE ORDERED	DATE SHIPPED	DATE RECEIVED	DATE OF DELIVERY	DATE OF DELIVERY
984S		01/07/10	01/07/10	01/15/10	T/S	DEST
NS	CERTIFICATE OF CONFORMANCE **	01/07/10	EA	1.	1.	
ST	.035	01/07/10	2D8E EA	40.	(40)	
SI	.007	01/07/10	2E1K EA	40.	(40)	
FIN HEX NUT						
FIN HEX NUT						
PKG STOCK - 2E2F	<<<<<<<<<<					
PKG STOCK - 2E2F	<<<<<<<<<<					
PKG STOCK - 2E1B	<<<<<<<<<<					
ST	.056	01/07/10	2E5C EA	15.	(15)	
S.S. LOCK WASHER						

3. OF
DYES

TOTAL
EIGHT

5 BKS

No returns accepted without prior authorization, nor of any special order items. All acceptable returns subject to a minimum 10% restocking charge, and must be accompanied by a copy of this invoice.

Received by **X**

Please print name

v10.18.12 186 / 424

PACKING LIST

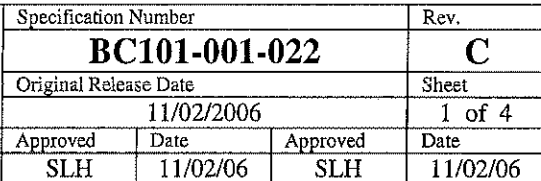
ORDER NO.	FILE NO.	DATE
01055031	123612	

S
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LO
D

EDEN CRYOGENICS, LLC.
8445 RAUSCH DRIVE
PLAIN CITY OH 43064

NT	ITEM	QTY	UNIT	DATE	PRICE	TOTAL	REMARKS
	>>>>>>>> PKG STOCK - 2E1C <<<<<<<<<<<<						
4	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4-7 S.S. FIN HEX NUT						
5	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
2	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
7	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
8	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
9	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
10	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
11	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
12	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
13	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
14	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
15	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
16	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
17	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
18	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
19	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
20	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
21	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
22	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
23	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
24	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
25	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
26	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
27	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
28	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
29	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
30	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
31	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
32	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
33	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
34	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
35	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
36	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
37	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
38	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
39	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
40	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
41	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
42	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
43	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
44	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
45	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
46	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
47	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
48	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
49	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
50	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
51	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
52	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
53	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
54	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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55	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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56	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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57	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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58	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
59	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
60	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
61	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
62	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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63	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
64	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
65	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
66	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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	1-3/4 S.S. LOCK WASHER						
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	1-3/4 S.S. LOCK WASHER						
71	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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72	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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73	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
74	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
75	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
76	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
77	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
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78	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
79	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
80	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
81	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
82	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
83	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
84	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
85	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
86	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
87	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
88	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
89	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
90	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
91	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
92	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
93	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
94	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
95	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
96	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
97	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
98	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
99	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						
100	FNKS125C ST .54 01/07/10 2E8D EA 63.						63.
	1-3/4 S.S. LOCK WASHER						

Received by X



22

Document	Date	Rev.	Description	# Pages

v10.18.12 188 / 424

Welding Procedure Specification (WPS)

**GTAW of Stainless Steel (P-8) Materials WITHOUT Impact Toughness Requirements.
Base Metal Thickness Range from 0.035 to 2 inch.**

Company Name Eden Cryogenics, LLC. By: John Warnement
 WPS No. BC101-001-022 Date: 11-2-2006 Supporting PQR No.(s) 001, 002 & 004
 Revision No. C Date 10-29-2009
 Welding Process(es) GTAW Type (s) Manual

JOINTS (QW-402)

Details

Joint Design See Page 4 for Weld Joint Details
 Backing With or Without
 Backing Material (Type)
☒ Metal ☐ Nonfusing Metal
☐ Nonmetallic ☐ Other

See Page 4 for Weld Joint Details**BASE METALS (QW-403)**

P-No. 8 Group No. All to P-No. 8 Group No. All

Examples of P8 Base Metals (all P8 Base Metals are qualified)
 Specification type and grade Types 304, 304L, 316, 316L

Thickness Range:
 Base Metal: Groove 0.035 to 2 inch Fillet ALL
 Other _____

FILLER METALS (QW-404)

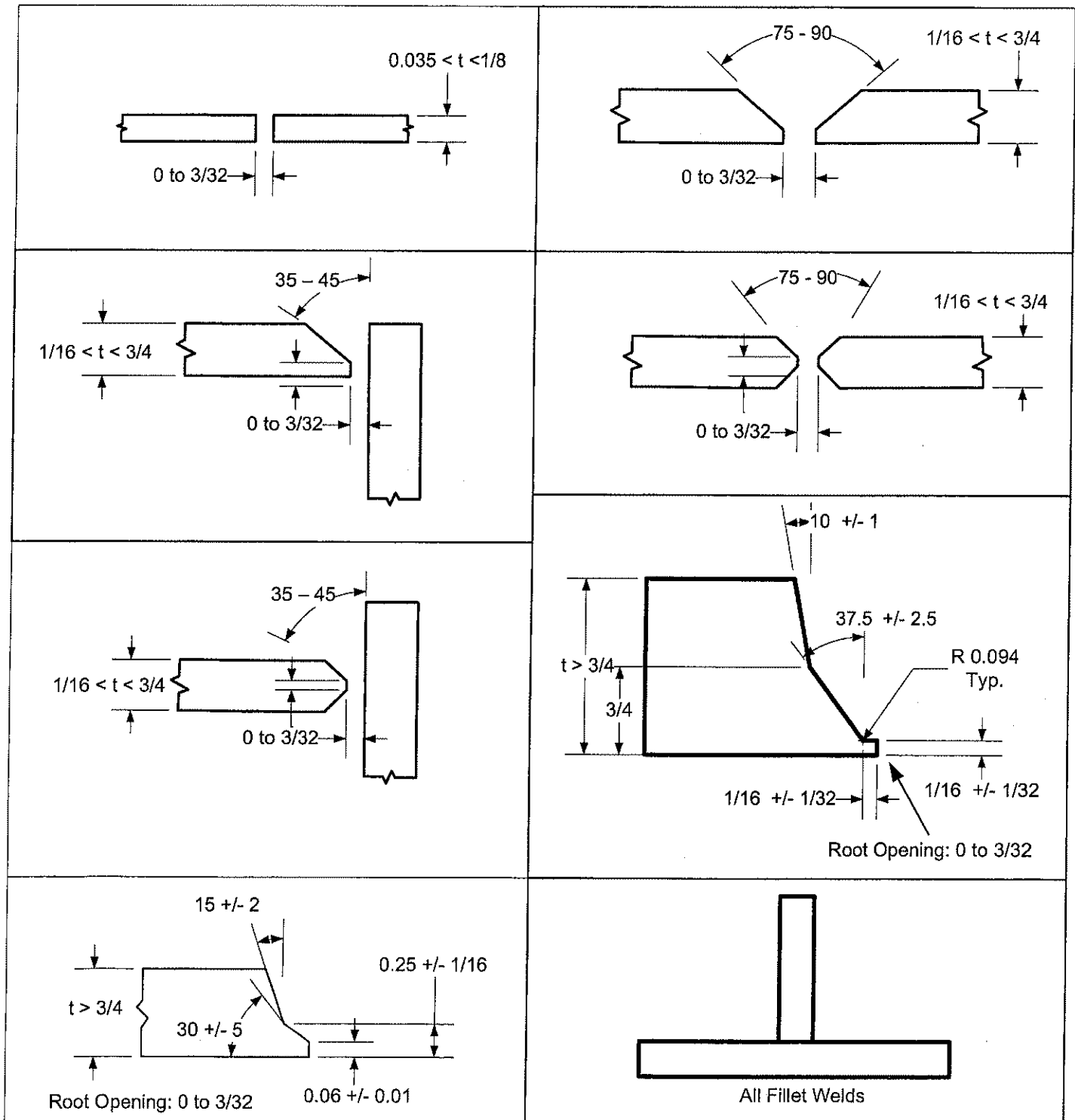
Spec. No. (SFA)	A5.9	Base Metals welded with Filler Metal on same row	
AWS No. (Class)		304 to 304	ER308 or ER308L
F-No.	6	304 to 304L	ER308 or ER308L
A-No.	8	304L to 304L	ER308L
Size of Filler Metal	0.035, 0.045, 1/16, 3/32 inch		
Weld Metal		316 to 316	ER316 or ER316L
Thickness Range:		316 to 316L	ER316 or ER316L
Groove	0.035 to 2 inch	316L to 316L	ER316L
Fillet	ALL		
Electrode-Flux (Class)	N/A		
Flux Trade Name	N/A		
Consumable Insert	N/A		

Other _____

POSITIONS (QW-405)		POST WELD HEAT TREATMENT (QW-407)			
Position(s) of Groove	ALL	Temperature Range		None	
Welding Progression:	Up <u> X </u> Down <u> </u>	Time Range		None	
Position(s) of Fillet	ALL				
PREHEAT (QW-406)		GAS (QW-408)			
Preheat Temp. Min.	70 °F		Gas(es)	(Mixture)	Flow Rate
Interpass Temp. Max.	350 °F	Shielding	Argon	100	20 - 40 cfh
Preheat Maintenance	None	Trailing	None		
		Backing	Argon	100	5 - 15 cfh
ELECTRICAL CHARACTERISTICS (QW-409)					
Current AC or DC	DC	Polarity		Straight	
Amps (Range)	20 - 250	Volts (Range)		10 - 18	
Tungsten Electrode Size and Type <u> 1/16 or 3/32-inch diameter 2% Thoriated </u>					
Mode of Metal Transfer for GMAW <u> N/A </u> (Spray arc, short circuiting arc, etc.)					
Electrode Wire feed speed range <u> N/A </u>					
TECHNIQUE (QW-410)					
String or Weave Bead	String or Weave				
Orifice or Gas Cup Size	No. 3 - 12				
Initial and Interpass Cleaning	Brush or grind to remove oxides and contaminants from weld joint surfaces and a minimum of 1 inch from weld joint edges. Use tools (e.g., brushes, grinding wheels, etc.) that have NOT been used on carbon steel.				
Method of Back Gouging	N/A				
Oscillation	N/A				
Contact Tube to Work Distance	N/A				
Multiple or Single Pass (per side)	Single or Multiple				
Multiple or Single Electrodes	Single				
Travel Speed (Range)	N/A				
Peening	None				
Other					

Weld Joint Designs:

If Weld Joint Design is NOT designated on Engineering Drawing use one of the applicable weld joint designs below.



WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Andrew Powers**

Identification No. **C-35**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002 & 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .5 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/> Plate				.5"		2"	
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, 5B, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :	Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	0.5 in.	2 in. Max	
Base Metal:	Pipe	3 layers minimum	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	0.035 in.		
Position qualified:		Plate	3G			ALL	
		Pipe	6G				
Vertical progression (uphill or downhill)		Uphill			Uphill ¹		
Inert gas backing (GTAW, PAW, GMAW)		Argon			With Backing Gas ²		
GTAW current type/polarity (AC, DCEP, DCEN)		DCEN			DCEN		
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

RESULTS

Visual Examination of Completed Weld (QW-302.4)

Passed

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type	Result	Type	Result
Side Bend 1 QW-462.2	Pass - No Indications	Root Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 2 QW-462.2	Pass - No Indications	Root Bend 2 QW-462.3(a) note b	Pass - No Indications
Side Bend 3 QW-462.2	Pass - No Indications	Face Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 4 QW-462.2	Pass - No Indications	Face Bend 2 QW-462.3(a) note b	Pass - No Indications

Mechanical testing by: John Warnement

Laboratory Test no. _____

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 12/23/09

By: John Meister

Revised from 10/24/06 QW-484A as Brehon Cryogenics

WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Tam Van Vo**

Identification No. **C-1**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002 & 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .375 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/> Plate				.375"		.75 in.	
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, SB, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :		Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	0.375 in.	.75 in. Max
Base Metal:		Pipe	3 layers minimum	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	0.035 in.	
Position qualified:		Plate				3G	ALL
		Pipe				6G	
Vertical progression (uphill or downhill)				Uphill		Uphill ¹	
Inert gas backing (GTAW, PAW, GMAW)				Argon		With Backing Gas ²	
GTAW current type/polarity (AC, DCEP, DCEN)				DCEN		DCEN	
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

RESULTS

Visual Examination of Completed Weld (QW-302.4)

Passed

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type	Result	Type	Result
Side Bend 1 QW-462.3(a)	Pass - No Indications	Root Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 2 QW-462.3(a)	Pass - No Indications	Root Bend 2 QW-462.3(a) note b	Pass - No Indications
Side Bend 3 QW-462.3(a)	Pass - No Indications	Face Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 4 QW-462.3(a)	Pass - No Indications	Face Bend 2 QW-462.3(a) note b	Pass - No Indications

Mechanical testing by: CTL Engineering

Laboratory Test no. _____

CTL Project No. 06030530COL
CTL Project No. 06030520COL

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 2/15/09

By: John Warnement

Revised from 10/24/06 QW-484A as Brehon Cryogenics

WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Richard Kennedy**

Identification No. **C-2**

Test Description

Identification of WPS followed **BC101-001-022**

☒ Test Coupon ☐ Production weld

Welded Samples for PQR No(s) **001, 002 & 004**

Specification of base metal(s) **SA-240 & A169-04**

Thickness: **0.035 & .500 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/> Plate				.500"		2 in.	
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, 5B, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :	Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	0.500 in.	2 in. Max	
Base Metal:	Pipe	3 layers minimum	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	0.035 in.		
Position qualified:		Plate	3G			ALL	
		Pipe	6G				
Vertical progression (uphill or downhill)		Uphill			Uphill ¹		
Inert gas backing (GTAW, PAW, GMAW)		Argon			With Backing Gas ²		
GTAW current type/polarity (AC, DCEP, DCEN)		DCEN			DCEN		
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

RESULTS

Visual Examination of Completed Weld (QW-302.4)

Passed

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type		Result		Type		Result	
Side Bend 1	QW-462.3(a)	Pass - No Indications		Root Bend 1	QW-462.3(a) note b	Pass - No Indications	
Side Bend 2	QW-462.3(a)	Pass - No Indications		Root Bend 2	QW-462.3(a) note b	Pass - No Indications	
Side Bend 3	QW-462.3(a)	Pass - No Indications		Face Bend 1	QW-462.3(a) note b	Pass - No Indications	
Side Bend 4	QW-462.3(a)	Pass - No Indications		Face Bend 2	QW-462.3(a) note b	Pass - No Indications	

Mechanical testing by: John Warnement

Laboratory Test no. _____

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 2/15/08

By: John Warnement

Revised from 10/24/06 QW-484A as Brehon Cryogenics

WELDER PERFORMANCE QUALIFICATIONS (WPO)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Bradley DeMent**

Identification No. **C-3**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002 & 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .500 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/>	Plate			.500"			
<input checked="" type="checkbox"/>	Pipe (enter diameter, if pipe or tube)			0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, 5B, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :	Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	0.500 in.		2 in. Max	
Base Metal:	Pipe	3 layers minimum	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	0.035 in.			
Position qualified:		Plate			3G	ALL	
		Pipe			6G		
Vertical progression (uphill or downhill)				Uphill		Uphill ¹	
Inert gas backing (GTAW, PAW, GMAW)				Argon		With Backing Gas ²	
GTAW current type/polarity (AC, DCEP, DCEN)				DCEN		DCEN	
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

RESULTS

Visual Examination of Completed Weld (QW-302.4)

Passed

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type		Result		Type		Result	
Side Bend 1	QW-462.3(a)	Pass	- No Indications	Root Bend 1	QW-462.3(a) note b	Pass	- No Indications
Side Bend 2	QW-462.3(a)	Pass	- No Indications	Root Bend 2	QW-462.3(a) note b	Pass	- No Indications
Side Bend 3	QW-462.3(a)	Pass	- No Indications	Face Bend 1	QW-462.3(a) note b	Pass	- No Indications
Side Bend 4	QW-462.3(a)	Pass	- No Indications	Face Bend 2	QW-462.3(a) note b	Pass	- No Indications

Mechanical testing by: John Warnement

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 2/5/07

By: John Warnement

Revised from 10/24/06 QW-484A as Brehon Cryogenics

WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Scott Walker**

Identification No. **C-10**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002 & 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .5 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/> Plate				.5"		2"	
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, 5B, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :	Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	0.5 in.	2 in. Max	
Base Metal:	Pipe	3 layers minimum	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	0.035 in.		
Position qualified:	Plate			3G		ALL	
	Pipe			6G			
Vertical progression (uphill or downhill)				Uphill		Uphill ¹	
Inert gas backing (GTAW, PAW, GMAW)				Argon		With Backing Gas ²	
GTAW current type/polarity (AC, DCEP, DCEN)				DCEN		DCEN	
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

RESULTS

Visual Examination of Completed Weld (QW-302.4)

Passed

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type	Result	Type	Result
Side Bend 1 QW-462.3(a)	Pass - No Indications	Root Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 2 QW-462.3(a)	Pass - No Indications	Root Bend 2 QW-462.3(a) note b	Pass - No Indications
Side Bend 3 QW-462.3(a)	Pass - No Indications	Face Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 4 QW-462.3(a)	Pass - No Indications	Face Bend 2 QW-462.3(a) note b	Pass - No Indications

Mechanical testing by: John Warnement

Laboratory Test no. _____

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 1/25/09

By: John Warnement

Revised from 10/24/06 QW-484A as Brehon Cryogenics

WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Brandon Arnold**

Identification No. **C-41**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002, 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .5 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/> Plate				.5"		2"	
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, 5B, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :	Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	0.5 in.	2 in. Max	
Base Metal:	Pipe	3 layers minimum	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	0.035 in.		
Position qualified:		Plate	3G			ALL	
		Pipe	6G				
Vertical progression (uphill or downhill)			Uphill			Uphill ¹	
Inert gas backing (GTAW, PAW, GMAW)			Argon			With Backing Gas ²	
GTAW current type/polarity (AC, DCEP, DCEN)			DCEN			DCEN	
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

Visual Examination of Completed Weld (QW-302.4) **Results: Passed**

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type	Result	Type	Result
Side Bend 1 QW-462.2	Pass - No Indications	Root Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 2 QW-462.2	Pass - No Indications	Root Bend 2 QW-462.3(a) note b	Pass - No Indications
Side Bend 3 QW-462.2	Pass - No Indications	Face Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 4 QW-462.2	Pass - No Indications	Face Bend 2 QW-462.3(a) note b	Pass - No Indications

Mechanical testing by: Eden Cryogenics

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 1/4/10

By: John Warnement

WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Sam Taylor**

Identification No. **C-45**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002, 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .500 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values	Range qualified
Welding process				GTAW	GTAW
Type (i.e., manual, semi-auto) used				Manual	Manual
Backing (metal, weld metal, double-welded, etc.)				With	With or Without
<input checked="" type="checkbox"/> Plate				.500"	2"
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.	0.5 to unlimited
Base metal P- or S-Number to P-or S-Number				8 to 8	P1 through P11, including P5A, 5B, & 5C
Filler metal or electrode specification(s) (SFA) (info only)				A5.9	
Filler metal or electrode classification(s) (info only)				ER308L	
Filler metal F-Number(s)				6	6
Consumable insert (GTAW or PAW)				None	None
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)	Bare (Solid)
Deposit thickness for each base metal form					
Base Metal :	Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	0.500 in.	2 in. Max
Base Metal:	Pipe	3 layers minimum	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	0.035 in.	
Position qualified: Plate				3G	ALL
Pipe				6G	
Vertical progression (uphill or downhill)				Uphill	Uphill ¹
Inert gas backing (GTAW, PAW, GMAW)				Argon	With Backing Gas ²
GTAW current type/polarity (AC, DCEP, DCEN)				DCEN	DCEN
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side					
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.					

Visual Examination of Completed Weld (QW-302.4) **Results: Passed**

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type (plate)	Result	Type (pipe)	Result
Side Bend 1 QW-462.2	Pass - No Indications	Root Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 2 QW-462.2	Pass - No Indications	Root Bend 2 QW-462.3(a) note b	Pass - No Indications
Side Bend 3 QW-462.2	Pass - No Indications	Face Bend 1 QW-462.3(a) note b	Pass - No Indications
Side Bend 4 QW-462.2	Pass - No Indications	Face Bend 2 QW-462.3(a) note b	Pass - No Indications

Mechanical testing by: Eden Cryogenics

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Eden Cryogenics

Date: 2/15/10

By: John Meister

WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(SEE QW-301, SECTION IX, ASME BOILER AND PRESSURE VESSEL CODE)

Welders Name **Mike Zimmerman**

Identification No. **C-46**

Test Description

Identification of WPS followed **BC101-001-022**
Welded Samples for PQR No(s) **001, 002, 004**
Specification of base metal(s) **SA-240 & A169-04**

☒ Test Coupon ☐ Production weld

Thickness: **0.035 & .500 in.**

Testing Conditions and Qualification Limits

Welding Variables (QW-350)				Actual values		Range qualified	
Welding process				GTAW		GTAW	
Type (i.e., manual, semi-auto) used				Manual		Manual	
Backing (metal, weld metal, double-welded, etc.)				With		With or Without	
<input checked="" type="checkbox"/> Plate				.500"		2"	
<input checked="" type="checkbox"/> Pipe (enter diameter, if pipe or tube)				0.5 inch dia.		0.5 to unlimited	
Base metal P- or S-Number to P-or S-Number				8 to 8		P1 through P11, including P5A, 5B, & 5C	
Filler metal or electrode specification(s) (SFA) (info only)				A5.9			
Filler metal or electrode classification(s) (info only)				ER308L			
Filler metal F-Number(s)				6		6	
Consumable insert (GTAW or PAW)				None		None	
Filler type (solid/metal or flux cored/powder (GTAW or PAW)				Bare (Solid)		Bare (Solid)	
Deposit thickness for each base metal form							
Base Metal :		Plate	3 layers minimum	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	0.500 in.	2 in. Max
Base Metal:		Pipe	3 layers minimum	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	0.035 in.	
Position qualified:		Plate		3G		ALL	
		Pipe		6G			
Vertical progression (uphill or downhill)				Uphill		Uphill ¹	
Inert gas backing (GTAW, PAW, GMAW)				Argon		With Backing Gas ²	
GTAW current type/polarity (AC, DCEP, DCEN)				DCEN		DCEN	
1. Cover Pass may be Uphill or Downhill. Root Pass may be uphill or downhill, if removed Root Pass is removed in preparation of welding second side							
2. Requalification is not required when welding a single-sided butt joint is welded with a backing strip or a double-welded butt joint or a fillet weld.							

Visual Examination of Completed Weld (QW-302.4)

Results: Passed

☒ Bend test; ☒ Transverse root and face [QW-462.3 (a)]; ☐ Longitudinal root and face [QW-462.3 (b)]; ☒ Side (QW-462.2);

Type (plate)		Result		Type (pipe)		Result	
Side Bend 1	QW-462.2	Pass	- No Indications	Root Bend 1	QW-462.3(a) note b	Pass	- No Indications
Side Bend 2	QW-462.2	Pass	- No Indications	Root Bend 2	QW-462.3(a) note b	Pass	- No Indications
Side Bend 3	QW-462.2	Pass	- No Indications	Face Bend 1	QW-462.3(a) note b	Pass	- No Indications
Side Bend 4	QW-462.2	Pass	- No Indications	Face Bend 2	QW-462.3(a) note b	Pass	- No Indications

Mechanical testing by: Eden Cryogenics

Welding supervised by John Warnement

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Date: 2/20/10

Organization: Eden Cryogenics

By: John Meister

FORM U-1A MA FACTURER'S DATA REPORT FOR PRESSURE VESSELS

(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

- Manufactured and certified by: Eden Cryogenics LLC. 8445 Rausch Drive Plain City, Ohio 43064
(Name and address of Manufacturer)
- Manufactured for: Fermi Research Alliance, LLC. P.O. Box 500 Batavia, IL 60510
(Name and address of Purchaser)
- Location of installation: Fermilab, Batavia Illinois
(Name and address)
- Type: Vertical 02128-01 BC-02128-5820-01 8 2010
(Horizontal or vertical tank) (Manufacturer's serial number) (Drawing number) (National Board number) (Year Built)
- The chemical and physical properties of all parts meet the requirements of material specification of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to the ASME rules, Section VIII, Division 1
to A08 -- 2007
(addenda(date)) (Code Case numbers) (Special Service per UG-120(d))
- Shell: SA-312-TP304 .1785" 0 10.42 39.5
(Material spec. number, grade) (Nominal thickness) (Corr. Allow.) (inner diameter) (length overall)
- Seams: welded -- 70% -- -- -- --
(Long. (welded, dbl., singl., lap,butt)) (R.T. (spot or full)) (Eff., %) (H.T. temp.) (Time, hr) (Girth. (welded, dbl., singl., lap,butt)) (R.T. (spot or full))
- Heads: (a) SA-312 TP304 (b) SA-312 TP304
(Material spec. number grade or type) (H.T. - time & temp) (Material spec. number grade or type) (H.T. - time & temp)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)	Top	.1875	0	--	1.91	2:1	--	--	--	--	X	A	NONE	70%
(b)	Bottom	.1875	0	--	1.91	2:1	--	--	--	--	X	A	NONE	70%

If removable, bolts used (describe other fastening) --

(Material spec. number grade, size, number)

9. MAWP 165 psi 15 psi at max temp. 932 deg F 70 deg F Min. design metal temp. -320 deg F at 165 psi
(Internal) (External) (Internal) (External)

Min. design metal temp. -- at -- Hydro. , pneu., or comb. test pressure pneu. test @ 188 psig

10. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain)	Number	Diameter or Size	Type	Material		Nominal Thickness	Reinforcement Material	How Attached	Location
				Nozzle	Flange				
inlet/outlet	2	1" nps	W.E.	304/304L SA-312	N/A	sch. 10 (.109")	--	UW 16.1 (c)	HEADS
fill	1	3" nps.	W.E.	304/304L SA-312	N/A	sch. 10 (.120")	--	UW 16.1 (c)	HEADS
thermowells	5	1.13" dia	CPL.	304/304L SA-182	N/A	.142"	--	UW 16.1 (c)	SHELL

11. Supports: Skirt no Lugs 3 Legs -- Others -- Attached --
(Yes or No) (Number) (Number) (Describe) (Where and how)

12. Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report:

(List the name of part, item number, Manufacturer's name and identifying stamp)

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number 37,118
expires Dec 13, 2010

Date 03/25/10 Co. Name EDEN CRYOGENICS LLC. Signed [Signature]
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by EDEN CRYOGENICS LLC. at 8445 RAUSCH DRIVE PLAIN CITY OHIO 43064

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of OHIO and employed by HSB-CT

have inspected the component described in this Manufacturer's Data Report on MARCH 25, 2010, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 3/25/10 Signed Brack Seesholtz Commissions HB# 13582A, OH874
(Authorized Inspector) (National Board (incl endorsements) State, Province and number)

FORM U-1A MA FACTURER'S DATA REPORT FOR ASSURE VESSELS

(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

- Manufactured and certified by: Eden Cryogenics LLC. 8445 Rausch Drive Plain City, Ohio 43064
(Name and address of Manufacturer)
- Manufactured for: Fermi Research Alliance, LLC. P.O. Box 500 Batavia, IL 60510
(Name and address of Purchaser)
- Location of installation: Fermilab, Batavia Illinois
(Name and address)
- Type: Vertical 02128-02 BC-02128-5820-02 9 2010
(Horizontal or vertical tank) (Manufacturer's serial number) (Drawing number) (National Board number) (Year Built)
- The chemical and physical properties of all parts meet the requirements of material specification of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to the ASME rules, Section VIII, Division 1 2007
to A08 -- -- -- --
(addenda(date)) (Code Case numbers) (Special Service per UG-120(d))
- Shell: SA-312-TP304 .1785" 0 10.42 39.5
(Material spec. number, grade) (Nominal thickness) (Corr. Allow.) (inner diameter) (length overall)
- Seams: welded -- 70% -- -- -- --
(Long. (welded, dbl., snl., lap,butt)) (R.T. (spot or full)) (Eff., %) (H.T. temp.) (Time, hr) (Girth. (welded, dbl., snl., lap,butt)) (R.T. (spot or full))
- Heads: (a) SA-312 TP304 (b) SA-312 TP304
(Material spec. number grade or type) (H.T. -- time & temp) (Material spec. number grade or type) (H.T. -- time & temp)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)	Top	.1875	0	--	1.91	2:1	--	--	--	--	X	A	NONE	70%
(b)	Bottom	.1875	0	--	1.91	2:1	--	--	--	--	X	A	NONE	70%

If removable, bolts used (describe other fastening) --

(Material spec. number grade, size, number)

9. MAWP 165 psi 15 psi at max temp. 932 deg F 70 deg F Min. design metal temp. -320 deg F at 165 psi
(Internal) (External) (Internal) (External)

Min. design metal temp. -- at -- Hydro. , pneu., or comb. test pressure pneu. test @ 188 psig

10. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain)	Number	Diameter or Size	Type	Material		Nominal Thickness	Reinforcement Material	How Attached	Location
				Nozzle	Flange				
inlet/outlet	2	1" nps	W.E.	304/304L SA-312	N/A	sch. 10 (.109")	--	UW 16.1 (c)	HEADS
fill	1	3" nps.	W.E.	304/304L SA-312	N/A	sch. 10 (.120")	--	UW 16.1 (c)	HEADS
thermowells	5	1.13" dia	CPL.	304/304L SA-182	N/A	.142"	--	UW 16.1 (c)	SHELL

11. Supports: Skirt no Lugs 3 Legs -- Others -- Attached --
(Yes or No) (Number) (Number) (Describe) (Where and how)

12. Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report:

(List the name of part, item number, Manufacturer's name and identifying stamp)

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number 37,118
expires Dec 13, 2010

Date 03/25/10 Co. Name EDEN CRYOGENICS LLC. Signed [Signature]
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by EDEN CRYOGENICS LLC. at 8445 RAUSCH DRIVE PLAIN CITY OHIO 43064

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of OHIO and employed by HSB-CT

have inspected the component described in this Manufacturer's Data Report on MARCH 25, 2010, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 3/25/10 Signed [Signature] Commissions HB#13582A, OH 874
(Authorized Inspector) (National Board (incl endorsements) State, Province and number)

FORM U-1A MA FACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by: Eden Cryogenics LLC. 8445 Rausch Drive Plain City, Ohio 43064
(Name and address of Manufacturer)
2. Manufactured for: Fermi Research Alliance, LLC. P.O. Box 500 Batavia, IL 60510
(Name and address of Purchaser)
3. Location of installation: Fermilab, Batavia Illinois
(Name and address)
4. Type: Vertical 02128-03 BC-02128-5820-03 10 2010
(Horizontal or vertical tank) (Manufacturer's serial number) (Drawing number) (National Board number) (Year Built)
5. The chemical and physical properties of all parts meet the requirements of material specification of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to the ASME rules, Section VIII, Division 1
to A08 -- 2007
(addenda(date)) (Code Case numbers) (Special Service per UG-120(d))
6. Shell: SA-312-TP304 .1785" 0 10.42 39.5
(Material spec. number, grade) (Nominal thickness) (Corr. Allow.) (inner diameter) (length overall)
7. Seams: welded -- 70% -- -- --
(Long. (welded, dbl., singl., lap,butt)) (R.T. (spot or full)) (Eff., %) (H.T. temp.) (Time, hr) (Girth. (welded, dbl., singl., lap,butt)) (R.T. (spot or full))
8. Heads: (a) SA-312 TP304 (b) SA-312 TP304
(Material spec. number grade or type) (H.T. - time & temp) (Material spec. number grade or type) (H.T. - time & temp)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
(a)	Top	.1875	0	--	1.91	2:1	--	--	--	--	X	A	NONE	70%
(b)	Bottom	.1875	0	--	1.91	2:1	--	--	--	--	X	A	NONE	70%

If removable, bolts used (describe other fastening) --

(Material spec. number grade, size, number)

9. MAWP 165 psi 15 psi at max temp. 932 deg F 70 deg F Min. design metal temp. -320 deg F at 165 psi
(Internal) (External) (Internal) (External)
- Min. design metal temp. -- at -- Hydro. , pneu., or comb. test pressure pneu. test @ 188 psig

10. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain)	Number	Diameter or Size	Type	Material		Nominal Thickness	Reinforcement Material	How Attached	Location
				Nozzle	Flange				
inlet/outlet	2	1" nps	W.E.	304/304L SA-312	N/A	sch. 10 (.109")	--	UW 16.1 (c)	HEADS
fill	1	3" nps.	W.E.	304/304L SA-312	N/A	sch. 10 (.120")	--	UW 16.1 (c)	HEADS
thermowells	5	1.13" dia	CPL.	304/304L SA-182	N/A	.142"	--	UW 16.1 (c)	SHELL

11. Supports: Skirt no Lugs 3 Legs -- Others -- Attached --
(Yes or No) (Number) (Number) (Describe) (Where and how)
12. Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report: (List the name of part, item number, Manufacturer's name and identifying stamp)

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number 37,118
expires Dec 13, 2010

Date 03/25/10 Co. Name EDEN CRYOGENICS LLC. Signed [Signature]
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by EDEN CRYOGENICS LLC. at 8445 RAUSCH DRIVE PLAIN CITY OHIO 43064
I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of OHIO and employed by HSB-CT
have inspected the component described in this Manufacturer's Data Report on MARCH 25, 2010, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

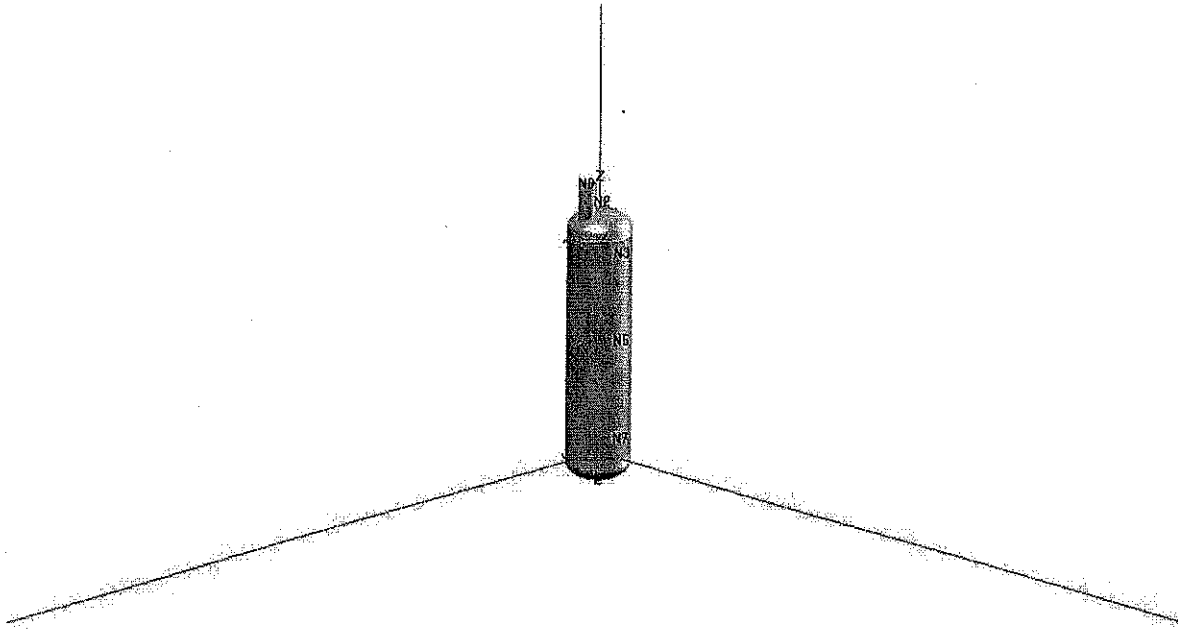
Date 3/25/10 Signed [Signature] Commissions NB#13582A, 04874
(Authorized Inspector) (National Board (incl endorsements) State, Province and number)

EDEN CRYOGENICS, LLC

8445 RAUSCH DRIVE

PLAIN CITY, OHIO 43064

USA



Pressure Vessel Design Calculations

Item: LAR PRESSURE VESSEL
Vessel No: 1
Customer: FERMI NATIONAL LABORATORY
Contract: BC-02128
Designer: ALLAN G. HANSON
Date: OCTOBER 22, 2009
Location: FERMI NATIONAL LABORATORY
Purchaser: TERRY TOPE
Vessel Name: LAR Pressure Vessel
Service: LIQUID ARGON
P.O. Number: BC-0218

Deficiencies Summary

No deficiencies found.

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
<u>N1</u>	Gas Outlet	1" Sch 10S	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N2</u>	Gas Inlet	1" Sch 10S	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N3</u>	Thermocouple	0.500" Class 3000 - threaded	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N4</u>	Copy of Thermocouple	0.500" Class 3000 - threaded	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N5</u>	Copy of Thermocouple	0.500" Class 3000 - threaded	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N6</u>	Copy of Thermocouple	0.500" Class 3000 - threaded	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N7</u>	Copy of Thermocouple	0.500" Class 3000 - threaded	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N8</u>	Fill Nozzle	3" Sch 10S	SA-312 TP304 Wld & sm/s pipe	No	No	No	N/A	N/A	N/A	N/A	N/A

Nozzle Summary

Nozzle mark	OD (in)	t (in)	Req t _n (in)	A ₁ ?	A ₂ ?	Shell			Reinforcement Pad		Corr (in)	A _a / A _r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t _{pad} (in)		
<u>N1</u>	1.315	0.109	0.1089	Yes	Yes	0.1875*	0.0858		N/A	N/A	0	156.6
<u>N2</u>	1.315	0.109	0.1089	Yes	Yes	0.1875*	0.0858		N/A	N/A	0	160.3
<u>N3</u>	1.125	0.1425	0.0714	Yes	Yes	0.18	0.119		N/A	N/A	0	100.0
<u>N4</u>	1.125	0.1425	0.0714	Yes	Yes	0.18	0.119		N/A	N/A	0	100.0
<u>N5</u>	1.125	0.1425	0.0714	Yes	Yes	0.18	0.119		N/A	N/A	0	100.0
<u>N6</u>	1.125	0.1425	0.0714	Yes	Yes	0.18	0.119		N/A	N/A	0	100.0
<u>N7</u>	1.125	0.1425	0.0714	Yes	Yes	0.18	0.119		N/A	N/A	0	100.0
<u>N8</u>	3.5	0.12	0.1031	Yes	Yes	0.1875*	0.0902		N/A	N/A	0	100.0

t_n: Nozzle thickness

Req t_n: Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a: Area available per UG-37, governing condition

A_r: Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

* Head minimum thickness after forming

Pressure Summary

Pressure Summary for Chamber bounded by Ellipsoidal Head #1 and Ellipsoidal Head #2

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MDMT (°F)	MDMT Exemption	Impact Tested
<u>Ellipsoidal Head #2</u>	165	932	304.16	422.45	-320	Note 1	No
<u>Straight Flange on Ellipsoidal Head #2</u>	165	932	262.77	364.96	-320	Note 2	No
<u>Cylinder #1</u>	165	932	252.42	350.58	-320	Note 2	No
<u>Straight Flange on Ellipsoidal Head #1</u>	165	932	262.77	364.96	-320	Note 2	No
<u>Ellipsoidal Head #1</u>	165	932	304.16	422.45	-320	Note 1	No
<u>Clip #1</u>	165	932	165	N/A	N/A	N/A	N/A
<u>Clip #2</u>	165	932	165	N/A	N/A	N/A	N/A
<u>Clip #3</u>	165	932	165	N/A	N/A	N/A	N/A
<u>Gas Outlet (N1)</u>	165	932	221.3	307.35	-320	Note 3	No
<u>Gas Inlet (N2)</u>	165	932	221.3	307.35	-320	Note 3	No
<u>Thermocouple (N3)</u>	165	932	273.56	379.94	-320	Note 4	No
<u>Copy of Thermocouple (N4)</u>	165	932	273.56	379.94	-320	Note 4	No
<u>Copy of Thermocouple (N5)</u>	165	932	273.56	379.94	-320	Note 4	No
<u>Copy of Thermocouple (N6)</u>	165	932	273.56	379.94	-320	Note 4	No
<u>Copy of Thermocouple (N7)</u>	165	932	273.56	379.94	-320	Note 4	No
<u>Fill Nozzle (N8)</u>	165	932	209.27	290.63	-320	Note 5	No

Chamber design MDMT is -320 °F

Chamber rated MDMT is -320 °F @ 165 psi

Chamber MAWP was used in the MDMT determination

Chamber MAWP hot & corroded is 165 psi @ 932 °F

Chamber MAP cold & new is 290.63 psi @ 70 °F

This pressure chamber is not designed for external pressure.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Material Impact test exempt per UHA-51(g)(coincident ratio = 0.31189)	
2.	Rated MDMT per UHA-51(d)(1)(a) = -320 °F	
3.	Impact test exempt per UHA-51(g)(coincident ratio = 0.04768)	
4.	Impact test exempt per UHA-51(g)(coincident ratio = 0.02793)	
5.	Impact test exempt per UHA-51(g)(coincident ratio = 0.12871)	

Design notes are available on the [Settings Summary](#) page.

Revision History

No.	Date	Operator	Notes
0	10/21/2009	ahanson	New vessel created ASME Section VIII Division 1 [Build 6263]

Settings Summary

COMPRESS Build 6263

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	0.0625" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	0.25"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25 and ≤ 1.50 " thick:	No
UG-37(a) shell tr calculation considers longitudinal stress:	No
Butt welds are tapered per Figure UCS-66.3(a).	

Hydro/Pneumatic Test

Shop Pneumatic Test Pressure:	1.1 times design P
Test liquid specific gravity:	1.00
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116 (e) Radiography:	None
UG-116 (f) Postweld heat treatment:	None

Code Cases/Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	Yes
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	Yes
Apply interpretation VIII-1-01-37:	Yes
No UCS-66.1 MDMT reduction:	No
No UCS-68(c) MDMT reduction:	No
Disallow UG-20(f) exemptions:	Yes

UG-22 Loadings

UG-22 (a) Internal or External Design Pressure :	Yes
UG-22 (b) Weight of the vessel and normal contents under operating or test conditions:	No
UG-22 (c) Superimposed static reactions from weight of attached equipment (external loads):	No
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	No
UG-22 (f) Wind reactions:	No
UG-22 (f) Seismic reactions:	No

Note: UG-22 (b),(c) and (f) loads only considered when supports are present.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
<u>Ellipsoidal Head #2</u>	SA-312 TP304 Wld & smls pipe	12.39 ID	3.285	0.1875*	0.1016	0	0.70	Internal
<u>Straight Flange on Ellipsoidal Head #2</u>	SA-312 TP304 Wld & smls pipe	12.39 ID	1.5	0.1875	0.1025	0	0.70	Internal
<u>Cylinder #1</u>	SA-312 TP304 Wld & smls pipe	12.39 ID	39.5	0.18	0.1025	0	0.70	Internal
<u>Straight Flange on Ellipsoidal Head #1</u>	SA-312 TP304 Wld & smls pipe	12.39 ID	1.5	0.1875	0.1025	0	0.70	Internal
<u>Ellipsoidal Head #1</u>	SA-312 TP304 Wld & smls pipe	12.39 ID	3.285	0.1875*	0.1016	0	0.70	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements							Surface Area ft ²
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid	
Ellipsoidal Head #2	12.6	12.6	0	0	0	0	17.3	2
Cylinder #1	81.2	81.2	0	0	0	0	171.9	11
Ellipsoidal Head #1	13.1	13.1	0	0	0	0	15.5	2
TOTAL:	106.9	106.9	0	0	0	0	204.8	14

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (lb) Contributed by Attachments									Surface Area ft²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads	
	New	Corroded	New	Corroded						
<u>Ellipsoidal Head #2</u>	0	0	2.7	2.7	0	0	0	0	0	0
<u>Cylinder #1</u>	0	0	0.3	0.3	0	0	0	0.4	0	0
<u>Ellipsoidal Head #1</u>	0	0	0.1	0.1	0	0	0	0	0	0
TOTAL:	0	0	3.2	3.2	0	0	0	0.4	0	1

Vessel operating weight, Corroded: 111 lb

Vessel operating weight, New: 111 lb

Vessel empty weight, Corroded: 111 lb

Vessel empty weight, New: 111 lb

Vessel test weight, New: 315 lb

Vessel surface area: 15 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 111 lb

Center of Gravity: 20.3248"

Vessel Capacity

Vessel Capacity** (New): 24 US gal

Vessel Capacity** (Corroded): 24 US gal

**The vessel capacity does not include volume of nozzle, piping or other attachments.

Pneumatic Test

Shop test pressure determination for Chamber bounded by Ellipsoidal Head #1 and Ellipsoidal Head #2 based on design P per UG-100(b)

Shop pneumatic test gauge pressure is 252.085 psi at 70 °F (the chamber design P = 165 psi)

The shop test is performed with the vessel in the vertical position.

Identifier	Local test pressure psi	Test liquid static head psi	UG-100 stress ratio	UG-100 pressure factor
Ellipsoidal Head #2 (1)	252.446	0.361	1.3889	1.10
Straight Flange on Ellipsoidal Head #2	252.446	0.361	1.3889	1.10
Cylinder #1	253.872	1.787	1.3889	1.10
Straight Flange on Ellipsoidal Head #1	253.926	1.841	1.3889	1.10
Ellipsoidal Head #1	254.038	1.953	1.3889	1.10
Copy of Thermocouple (N4)	252.782	0.697	1.3889	1.10
Copy of Thermocouple (N5)	253.103	1.017	1.3889	1.10
Copy of Thermocouple (N6)	253.423	1.338	1.3889	1.10
Copy of Thermocouple (N7)	253.744	1.658	1.3889	1.10
Fill Nozzle (N8)	252.295	0.209	1.3889	1.10
Gas Inlet (N2)	252.275	0.19	1.3889	1.10
Gas Outlet (N1)	254.08	1.995	1.3889	1.10
Thermocouple (N3)	252.534	0.448	1.3889	1.10

Notes:

(1) Ellipsoidal Head #2 limits the UG-100 stress ratio.

The field test condition has not been investigated for the Chamber bounded by Ellipsoidal Head #1 and Ellipsoidal Head #2.

Cylinder #1

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Component: Cylinder
Material specification: SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Pipe NPS and Schedule: 12" Sch 10S
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 165 \text{ psi @ } 932 \text{ °F}$

Static liquid head:

$$P_{lv} = 1.79 \text{ psi} \quad (\text{SG} = 1, H_s = 49.5", \text{Vertical test head})$$

Corrosion allowance Inner $C = 0"$ Outer $C = 0"$

Design MDMT = -320 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - None UW-11(c) Type 1
Top circumferential joint - None UW-11(c) Type 2
Bottom circumferential joint - None UW-11(c) Type 1

Estimated weight New = 81.4 lb corr = 81.4 lb
Capacity New = 20.62 US gal corr = 20.62 US gal

ID = 12.39"
Length $L_o = 39.5"$
 $t = 0.18"$

Design thickness, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} t &= P \cdot R / (S \cdot E - 0.60 \cdot P) + \text{Corrosion} \\ &= 165 \cdot 6.195 / (14,400 \cdot 0.70 - 0.60 \cdot 165) + 0 \\ &= 0.1025" \end{aligned}$$

Maximum allowable working pressure, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) - P_s \\ &= 14,400 \cdot 0.70 \cdot 0.1575 / (6.195 + 0.60 \cdot 0.1575) - 0 \\ &= 252.42 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) \\ &= 20,000 \cdot 0.70 \cdot 0.1575 / (6.195 + 0.60 \cdot 0.1575) \\ &= 350.58 \text{ psi} \end{aligned}$$

Ellipsoidal Head #2

ASME Section VIII, Division 1, 2007 Edition, A08 Addenda

Component: Ellipsoidal Head
Material Specification: SA-312 TP304 Wld & smls pipe (II-D p.90, ln. 15)
Material Impact test exempt per UHA-51(g)(coincident ratio = 0.31189)

Internal design pressure: $P = 165 \text{ psi @ } 932 \text{ }^{\circ}\text{F}$

Static liquid head:

$P_s = 0 \text{ psi}$ ($SG=1$, $H_s=0''$ Operating head)
 $P_{tv} = 0.3068 \text{ psi}$ ($SG=1$, $H_s=8.5''$ Vertical test head)

Corrosion allowance: Inner $C = 0''$ Outer $C = 0''$

Design MDMT = -320°F No impact test performed
Rated MDMT = -320°F Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - None UW-11(c) Type 1
Head to shell seam - None UW-11(c) Type 2

Estimated weight*: new = 12.6 lb corr = 12.6 lb
Capacity*: new = 1.9 US gal corr = 1.9 US gal
* includes straight flange

Inner diameter = 12.39"
Minimum head thickness = 0.1875"
Head ratio $D/2h$ = 2 (new)
Head ratio $D/2h$ = 2 (corroded)
Straight flange length L_{sf} = 1.5"
Nominal straight flange thickness t_{sf} = 0.1875"

Results Summary

The governing condition is internal pressure.
Minimum thickness per UG-16 = $0.0625'' + 0'' = 0.0625''$
Design thickness due to internal pressure (t) = 0.1016''
Maximum allowable working pressure (MAWP) = 304.16 psi
Maximum allowable pressure (MAP) = 422.45 psi

Design thickness for internal pressure, (Corroded at 932 °F) UG-32(d)(1)

$$\begin{aligned} t &= P \cdot D / (2 \cdot S \cdot E - 0.2 \cdot P) + \text{Corrosion} \\ &= 165 \cdot 12.39 / (2 \cdot 14,400 \cdot 0.7 - 0.2 \cdot 165) + 0 \\ &= 0.1016'' \end{aligned}$$

The head internal pressure design thickness is 0.1016''.

Maximum allowable working pressure, (Corroded at 932 °F) UG-32(d)(1)

$$\begin{aligned} P &= 2SEt / (D + 0.2t) - P_s \\ &= 2 \cdot 14,400 \cdot 0.7 \cdot 0.1875 / (12.39 + 0.2 \cdot 0.1875) - 0 \\ &= 304.16 \text{ psi} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 304.16 psi.

Maximum allowable pressure, (New at 70 °F) UG-32(d)(1)

$$\begin{aligned} P &= 2SEt / (D + 0.2t) - P_s \\ &= 2 \cdot 20,000 \cdot 0.7 \cdot 0.1875 / (12.39 + 0.2 \cdot 0.1875) - 0 \\ &= 422.45 \text{ psi} \end{aligned}$$

The maximum allowable pressure (MAP) is 422.45 psi.

% Forming strain - UHA-44(a)(2)(b)

$$\begin{aligned} EFE &= (75t / R_f) \cdot (1 - R_f / R_o) \\ &= (75 \cdot 0.1875 / 2.2001) \cdot (1 - 2.2001 / \infty) \\ &= 6.3919\% \end{aligned}$$

Straight Flange on Ellipsoidal Head #2

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Component: Straight Flange
Material specification: SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 165 \text{ psi @ } 932 \text{ °F}$

Static liquid head:

$P_{tv} = 0.36 \text{ psi}$ (SG = 1, $H_s = 10''$, Vertical test head)

Corrosion allowance Inner C = 0" Outer C = 0"

Design MDMT = -320 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - None UW-11(c) Type 1
Circumferential joint - None UW-11(c) Type 2

Estimated weight New = 3.2 lb corr = 3.2 lb
Capacity New = 0.78 US gal corr = 0.78 US gal

ID = 12.39"
Length $L_c = 1.5''$
 $t = 0.1875''$

Design thickness, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} t &= P \cdot R / (S \cdot E - 0.60 \cdot P) + \text{Corrosion} \\ &= 165 \cdot 6.195 / (14,400 \cdot 0.70 - 0.60 \cdot 165) + 0 \\ &= 0.1025'' \end{aligned}$$

Maximum allowable working pressure, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) - P_s \\ &= 14,400 \cdot 0.70 \cdot 0.1641 / (6.195 + 0.60 \cdot 0.1641) - 0 \\ &= 262.77 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) \\ &= 20,000 \cdot 0.70 \cdot 0.1641 / (6.195 + 0.60 \cdot 0.1641) \\ &= 364.96 \text{ psi} \end{aligned}$$

Straight Flange on Ellipsoidal Head #1

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Component: Straight Flange
Material specification: SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 165$ psi @ 932 °F

Static liquid head:

$P_{lv} = 1.84$ psi (SG = 1, $H_s = 51$ ", Vertical test head)

Corrosion allowance Inner C = 0" Outer C = 0"

Design MDMT = -320 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - None UW-11(c) Type 1
Circumferential joint - None UW-11(c) Type 1

Estimated weight New = 3.2 lb corr = 3.2 lb
Capacity New = 0.78 US gal corr = 0.78 US gal

ID = 12.39"
Length $L_c = 1.5$ "
 $t = 0.1875$ "

Design thickness, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} t &= P \cdot R / (S \cdot E - 0.60 \cdot P) + \text{Corrosion} \\ &= 165 \cdot 6.195 / (14,400 \cdot 0.70 - 0.60 \cdot 165) + 0 \\ &= 0.1025" \end{aligned}$$

Maximum allowable working pressure, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) - P_s \\ &= 14,400 \cdot 0.70 \cdot 0.1641 / (6.195 + 0.60 \cdot 0.1641) - 0 \\ &= 262.77 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) \\ &= 20,000 \cdot 0.70 \cdot 0.1641 / (6.195 + 0.60 \cdot 0.1641) \\ &= 364.96 \text{ psi} \end{aligned}$$

Ellipsoidal Head #1

ASME Section VIII, Division 1, 2007 Edition, A08 Addenda

Component: Ellipsoidal Head
Material Specification: SA-312 TP304 Wld & smls pipe (II-D p.90, ln. 15)
Material Impact test exempt per UHA-51(g)(coincident ratio = 0.31189)

Internal design pressure: $P = 165 \text{ psi @ } 932^\circ\text{F}$

Static liquid head:

$P_s = 0 \text{ psi (SG=1, } H_s=0'' \text{ Operating head)}$
 $P_{tv} = 1.9528 \text{ psi (SG=1, } H_s=54.0975'' \text{ Vertical test head)}$

Corrosion allowance: Inner $C = 0''$ Outer $C = 0''$

Design MDMT = -320°F No impact test performed
Rated MDMT = -320°F Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - None UW-11(c) Type 1
Head to shell seam - None UW-11(c) Type 1

Estimated weight*: new = 13.1 lb corr = 13.1 lb
Capacity*: new = 1.9 US gal corr = 1.9 US gal

* includes straight flange

Inner diameter = 12.39"
Minimum head thickness = 0.1875"
Head ratio $D/2h$ = 2 (new)
Head ratio $D/2h$ = 2 (corroded)
Straight flange length L_{sf} = 1.5"
Nominal straight flange thickness t_{sf} = 0.1875"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16 = $0.0625'' + 0'' = 0.0625''$
Design thickness due to internal pressure (t) = 0.1016''
Maximum allowable working pressure (MAWP) = 304.16 psi
Maximum allowable pressure (MAP) = 422.45 psi

Design thickness for internal pressure, (Corroded at 932°F) UG-32(d)(1)

$t = \frac{P \cdot D}{(2 \cdot S \cdot E - 0.2 \cdot P)} + \text{Corrosion}$
 $= \frac{165 \cdot 12.39}{(2 \cdot 14,400 \cdot 0.7 - 0.2 \cdot 165)} + 0$
 $= 0.1016''$

The head internal pressure design thickness is 0.1016''.

Maximum allowable working pressure, (Corroded at 932 °F) UG-32(d)(1)

$$\begin{aligned} P &= 2SEt / (D + 0.2t) - P_s \\ &= 2 \cdot 14,400 \cdot 0.7 \cdot 0.1875 / (12.39 + 0.2 \cdot 0.1875) - 0 \\ &= 304.16 \text{ psi} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 304.16 psi.

Maximum allowable pressure, (New at 70 °F) UG-32(d)(1)

$$\begin{aligned} P &= 2SEt / (D + 0.2t) - P_s \\ &= 2 \cdot 20,000 \cdot 0.7 \cdot 0.1875 / (12.39 + 0.2 \cdot 0.1875) - 0 \\ &= 422.45 \text{ psi} \end{aligned}$$

The maximum allowable pressure (MAP) is 422.45 psi.

% Forming strain - UHA-44(a)(2)(b)

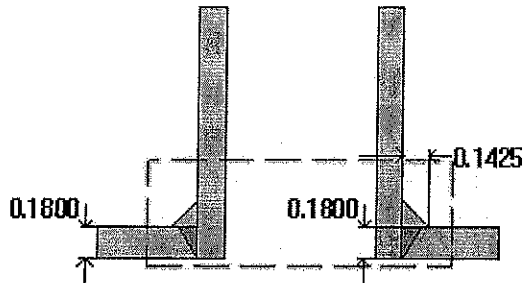
$$\begin{aligned} EFE &= (75t / R_i) \cdot (1 - R_i / R_o) \\ &= (75 \cdot 0.1875 / 2.2001) \cdot (1 - 2.2001 / \infty) \\ &= 6.3919\% \end{aligned}$$

Copy of Thermocouple (N4)

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$$t_{w(lower)} = 0.18 \text{ in}$$

$$Leg_{41} = 0.1425 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	0.500" Class 3000 - threaded
Nozzle orientation:	150°
Local vessel minimum thickness:	0.1575 in
Nozzle center line offset to datum line:	30.62 in
End of nozzle to shell center:	6.625 in
Nozzle inside diameter, new:	0.84 in
Nozzle nominal wall thickness:	0.1425 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.25 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 273.56 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 273.56 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(0.1575 - 0), 2.5*(0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P*R_n/(S_n*E - 0.6*P) \\
 &= 273.557*0.42/(14,400*1 - 0.6*273.557) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 6.195 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.119 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.1} \text{ in}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0125} \text{ in}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0125 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0089 \text{ in}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.0672} \text{ in}^2$$

$$\begin{aligned}
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2 \\
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.1425^2 \cdot 1 \\
 &= \underline{0.0203} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.0125 + 0.0672 + 0.0203 \\
 &= \underline{0.1} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = \underline{0.0997} \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 \times 0.1425 = 0.1247$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²) For P = 379.94 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 379.94 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \times (0.1575 - 0), 2.5 \times (0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \times R_n / (S_n \times E - 0.6 \times P) \\
 &= 379.938 \times 0.42 / (20,000 \times 1 - 0.6 \times 379.938) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\ &= 379.938 \cdot 6.195 / (20,000 \cdot 1 - 0.6 \cdot 379.938) \\ &= 0.119 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0125} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0125 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0089 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.0672} \text{ in}^2$$

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \\ &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1425^2 \cdot 1 \\ &= \underline{0.0203} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.0125 + 0.0672 + 0.0203 \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

As $\text{Area} \geq A$ the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{min} = 0.0997 \text{ in}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 * 0.1425 = 0.1247 \text{ in}$

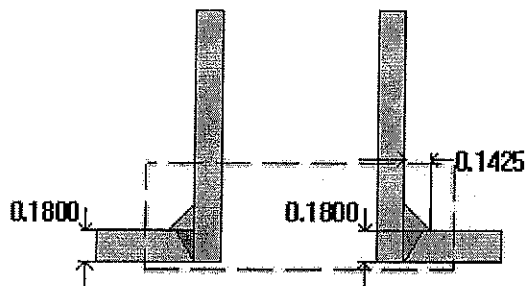
The nozzle neck thickness is adequate.

Copy of Thermocouple (N5)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.18 \text{ in}$$

$$\text{Leg}_{41} = 0.1425 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	0.500" Class 3000 - threaded
Nozzle orientation:	0°
Local vessel minimum thickness:	0.1575 in
Nozzle center line offset to datum line:	21.74 in
End of nozzle to shell center:	6.625 in
Nozzle inside diameter, new:	0.84 in
Nozzle nominal wall thickness:	0.1425 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.25 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 273.56 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 273.56 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.1575 - 0), 2.5*(0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 0.42 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 6.195 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.119 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.1} \text{ in}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.0125} \text{ in}^2$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0125 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0089 \text{ in}^2
 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0672} \text{ in}^2$

$$\begin{aligned}
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2 \\
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.1425^2 \cdot 1 \\
 &= \underline{0.0203} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.0125 + 0.0672 + 0.0203 \\
 &= \underline{0.1} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = \underline{0.0997 \text{ in}}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625 \text{ in}}$

Available nozzle wall thickness new, $t_n = 0.875 \times 0.1425 = 0.1247$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²) For P = 379.94 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg 41)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 379.94 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5 \times (0.1575 - 0), 2.5 \times (0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_{rn} &= P \times R_n / (S_n \times E - 0.6 \times P) \\
 &= 379.938 \times 0.42 / (20,000 \times 1 - 0.6 \times 379.938) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\ &= 379.938 \cdot 6.195 / (20,000 \cdot 1 - 0.6 \cdot 379.938) \\ &= 0.119 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0125} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0125 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0089 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.0672} \text{ in}^2$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1425^2 \cdot 1 \\ &= \underline{0.0203} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.0125 + 0.0672 + 0.0203 \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$
 $t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7t_{\min} = \underline{0.0997} \text{ in}$
 $t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in } (E = 1)$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

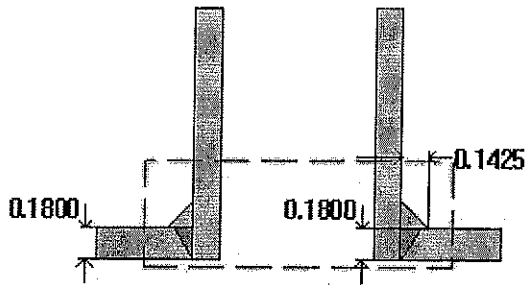
Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.1425 = 0.1247 \text{ in}$

The nozzle neck thickness is adequate.

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.18 \text{ in}$$

$$\text{Leg}_{41} = 0.1425 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	0.500" Class 3000 - threaded
Nozzle orientation:	150°
Local vessel minimum thickness:	0.1575 in
Nozzle center line offset to datum line:	12.86 in
End of nozzle to shell center:	6.625 in
Nozzle inside diameter, new:	0.84 in
Nozzle nominal wall thickness:	0.1425 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.25 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 273.56 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg 41)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 273.56 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_n) \\
 &= \text{MIN}(2.5*(0.1575 - 0), 2.5*(0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 0.42 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 6.195 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.119 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$\begin{aligned}
 f_{r1} &= \text{lesser of } 1 \text{ or } S_n / S_v = 1 \\
 f_{r2} &= \text{lesser of } 1 \text{ or } S_n / S_v = 1
 \end{aligned}$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.1 \text{ in}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0.0125 in²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0125 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0089 \text{ in}^2
 \end{aligned}$$

A_2 = smaller of the following = 0.0672 in²

$$\begin{aligned}
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2 \\
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.1425^2 \cdot 1 \\
 &= \underline{0.0203 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.0125 + 0.0672 + 0.0203 \\
 &= \underline{0.1 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{min} = \underline{0.0997} \text{ in}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 \times 0.1425 = 0.1247$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 379.94 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary

The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary

Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 379.94 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\&= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\&= 0.84 \text{ in}\end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_o) \\&= \text{MIN}(2.5 \times (0.1575 - 0), 2.5 \times (0.1425 - 0) + 0) \\&= 0.3563 \text{ in}\end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}t_{rn} &= P \times R_n / (S_n \times E - 0.6 \times P) \\&= 379.938 \times 0.42 / (20,000 \times 1 - 0.6 \times 379.938) \\&= 0.0081 \text{ in}\end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\ &= 379.938 \cdot 6.195 / (20,000 \cdot 1 - 0.6 \cdot 379.938) \\ &= 0.119 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.0125} \text{ in}^2$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0125 \text{ in}^2 \\ \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0089 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0672} \text{ in}^2$

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \\ \\ &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1425^2 \cdot 1 \\ &= \underline{0.0203} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.0125 + 0.0672 + 0.0203 \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.0997} \text{ in}$

$t_{c(\text{actual})} = 0.7*\text{Leg} = 0.7*0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

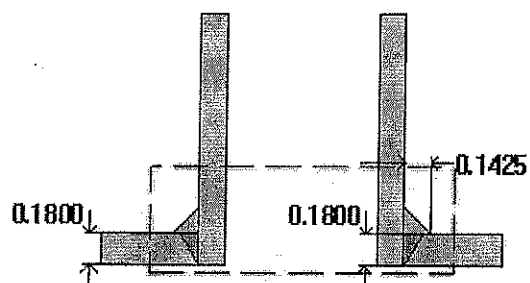
Available nozzle wall thickness new, $t_n = 0.875*0.1425 = 0.1247 \text{ in}$

The nozzle neck thickness is adequate.

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.18 \text{ in}$$

$$\text{Leg}_{41} = 0.1425 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	0.500" Class 3000 - threaded
Nozzle orientation:	0°
Local vessel minimum thickness:	0.1575 in
Nozzle center line offset to datum line:	3.98 in
End of nozzle to shell center:	6.625 in
Nozzle inside diameter, new:	0.84 in
Nozzle nominal wall thickness:	0.1425 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.25 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 273.56 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 273.56 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.1575 - 0), 2.5*(0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P*R_n/(S_n*E - 0.6*P) \\
 &= 273.557*0.42/(14,400*1 - 0.6*273.557) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 6.195 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.119 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.1 \text{ in}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0.0125 in²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0125 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0089 \text{ in}^2
 \end{aligned}$$

A_2 = smaller of the following = 0.0672 in²

$$\begin{aligned}
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2 \\
 &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.1425^2 \cdot 1 \\
 &= \underline{0.0203 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.0125 + 0.0672 + 0.0203 \\
 &= \underline{0.1 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{min} = \underline{0.0997} \text{ in}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 \times 0.1425 = 0.1247$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²) For P = 379.94 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 379.94 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \times (0.1575 - 0), 2.5 \times (0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \times R_n / (S_n \times E - 0.6 \times P) \\
 &= 379.938 \times 0.42 / (20,000 \times 1 - 0.6 \times 379.938) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\ &= 379.938 \cdot 6.195 / (20,000 \cdot 1 - 0.6 \cdot 379.938) \\ &= 0.119 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0.0125 in²

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0125 \text{ in}^2 \\ \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0089 \text{ in}^2 \end{aligned}$$

A_2 = smaller of the following = 0.0672 in²

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \\ \\ &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1425^2 \cdot 1 \\ &= \underline{0.0203} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.0125 + 0.0672 + 0.0203 \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{min} = 0.0997 \text{ in}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 * 0.1425 = 0.1247 \text{ in}$

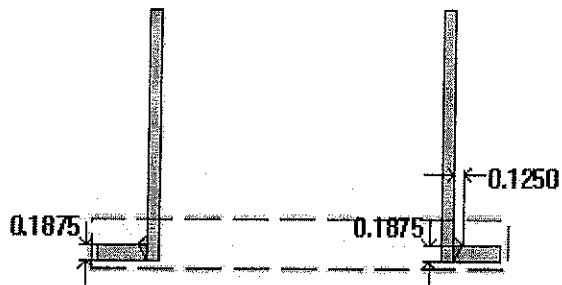
The nozzle neck thickness is adequate.

Fill Nozzle (N8)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.125 \text{ in}$$



Note: round inside edges per UG-78(c)

Located on:	Ellipsoidal Head #2
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	3" Sch 10S
Nozzle orientation:	90°
Calculated as hillside:	yes
Local vessel minimum thickness:	0.1875 in
End of nozzle to datum line:	49.5 in
Nozzle inside diameter, new:	3.26 in
Nozzle nominal wall thickness:	0.12 in
Nozzle corrosion allowance:	0 in
Opening chord length:	3.5004 in
Projection available outside vessel, Lpr:	5.3592 in
Distance to head center, R:	3.62 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 209.27 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.3156	0.3156	0.2423	0.0577	--	--	0.0156	0.0902	0.105

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.084	0.0875	weld size is adequate

Calculations for internal pressure 209.27 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.12871).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.5004, 1.7502 + (0.12 - 0) + (0.1875 - 0)) \\
 &= 3.5004 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.1875 - 0), 2.5*(0.12 - 0) + 0) \\
 &= 0.3 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P*R_n/(S_n*E - 0.6*P) \\
 &= 209.2707*1.63/(14,400*1 - 0.6*209.2707) \\
 &= 0.0239 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot D / (2 \cdot S \cdot E - 0.2 \cdot P) \\
 &= 209.27 \cdot 12.39 / (2 \cdot 14,400 \cdot 1 - 0.2 \cdot 209.27) \\
 &= 0.0902"
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 3.5004 \cdot 0.0902 \cdot 1 + 2 \cdot 0.12 \cdot 0.0902 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.3156} \text{ in}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0.2423 in²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 3.5004 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) - 2 \cdot 0.12 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) \cdot (1 - 1) \\
 &= 0.2423 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1875 + 0.12) \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) - 2 \cdot 0.12 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) \cdot (1 - 1) \\
 &= 0.0426 \text{ in}^2
 \end{aligned}$$

A_2 = smaller of the following = 0.0577 in²

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (0.12 - 0.0239) \cdot 1 \cdot 0.1875 \\
 &= 0.0901 \text{ in}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (0.12 - 0.0239) \cdot 1 \cdot 0.12 \\
 &= 0.0577 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.125^2 \cdot 1 \\
 &= \underline{0.0156} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.2423 + 0.0577 + 0.0156 \\
 &= \underline{0.3156} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.12 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.084 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.125 = 0.0875 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1} = 0.0239 \text{ in (E=1)}$

Wall thickness per UG-45(b)(1): $t_{r2} = 0.0902 \text{ in}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 0.189 \text{ in}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 0.0902 \text{ in}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 0.0902 \text{ in}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.0902$ in

Available nozzle wall thickness new, $t_n = 0.875 \times 0.12 = 0.105$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 290.63 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.3157	0.3157	0.2424	0.0577	--	--	0.0156	0.0902	0.105

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg 41)	0.084	0.0875	weld size is adequate

Calculations for internal pressure 290.63 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.12871).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.5018, 1.7509 + (0.12 - 0) + (0.1875 - 0)) \\
 &= 3.5018 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5 \times (0.1875 - 0), 2.5 \times (0.12 - 0) + 0) \\
 &= 0.3 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \times R_n / (S_n \times E - 0.6 \times P) \\
 &= 290.6275 \times 1.63 / (20,000 \times 1 - 0.6 \times 290.6275)
 \end{aligned}$$

$$= 0.0239 \text{ in}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot D \cdot K / (2 \cdot S \cdot E - 0.2 \cdot P) \\ &= 290.63 \cdot 12.39 \cdot 1 / (2 \cdot 20,000 \cdot 1 - 0.2 \cdot 290.63) \\ &= 0.0902'' \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.5018 \cdot 0.0902 \cdot 1 + 2 \cdot 0.12 \cdot 0.0902 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.3157 \text{ in}^2} \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.2424 \text{ in}^2}$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.5018 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) - 2 \cdot 0.12 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) \cdot (1 - 1) \\ &= 0.2424 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1875 + 0.12) \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) - 2 \cdot 0.12 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0902) \cdot (1 - 1) \\ &= 0.0426 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.0577 \text{ in}^2}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.12 - 0.0239) \cdot 1 \cdot 0.1875 \\ &= 0.0901 \text{ in}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.12 - 0.0239) \cdot 1 \cdot 0.12 \\ &= 0.0577 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.125^2 \cdot 1 \\ &= \underline{0.0156 \text{ in}^2} \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.2424 + 0.0577 + 0.0156 \\ &= \underline{0.3157 \text{ in}^2} \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.12 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = \underline{0.084} \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.125 = 0.0875 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1} = 0.0239 \text{ in } (E = 1)$

Wall thickness per UG-45(b)(1): $t_{r2} = 0.0902 \text{ in}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 0.189 \text{ in}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 0.0902 \text{ in}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 0.0902 \text{ in}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.0902} \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 * 0.12 = 0.105 \text{ in}$

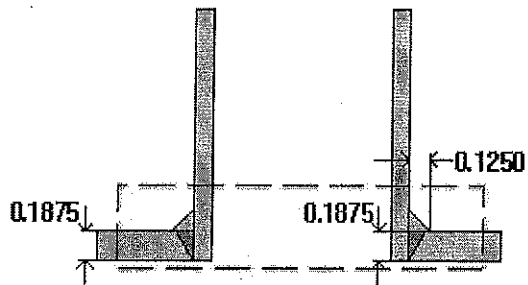
The nozzle neck thickness is adequate.

Gas Inlet (N2)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.125 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Ellipsoidal Head #2
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	1" Sch 10S
Nozzle orientation:	270°
Calculated as hillside:	yes
Local vessel minimum thickness:	0.1875 in
End of nozzle to datum line:	45.5 in
Nozzle inside diameter, new:	1.097 in
Nozzle nominal wall thickness:	0.109 in
Nozzle corrosion allowance:	0 in
Opening chord length:	1.1007 in
Projection available outside vessel, Lpr:	1.2197 in
Distance to head center, R:	1 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

The thickness requirements of UG-45 govern the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 221.3 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.0945	0.1514	0.081	0.0548	--	--	0.0156	0.0953	0.0954

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0763	0.0875	weld size is adequate

Calculations for internal pressure 221.3 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.04768).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.1007, 0.5504 + (0.109 - 0) + (0.1875 - 0)) \\
 &= 1.1007 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(0.1875 - 0), 2.5*(0.109 - 0) + 0) \\
 &= 0.2725 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 221.2951 \cdot 0.5485 / (14,400 \cdot 1 - 0.6 \cdot 221.2951) \\
 &= 0.0085 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P \cdot K_1 \cdot D / (2 \cdot S \cdot E - 0.2 \cdot P) \\
 &= 221.2951 \cdot 0.9 \cdot 12.39 / (2 \cdot 14,400 \cdot 1 - 0.2 \cdot 221.2951) \\
 &= 0.0858 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 1.1007 \cdot 0.0858 \cdot 1 + 2 \cdot 0.109 \cdot 0.0858 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.0945 \text{ in}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0.081 in²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 1.1007 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\
 &= 0.081 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1875 + 0.109) \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\
 &= 0.0436 \text{ in}^2
 \end{aligned}$$

A_2 = smaller of the following = 0.0548 in²

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.1875 \\
 &= 0.0942 \text{ in}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.109 \\
 &= 0.0548 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.125^2 \cdot 1 \\
 &= \underline{0.0156 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.081 + 0.0548 + 0.0156 \\
 &= \underline{0.1514 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.109 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{min} = \underline{0.0763} \text{ in}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 0.125 = 0.0875 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1} = 0.0085 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1): $t_{r2} = 0.0953 \text{ in}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 0.1164 \text{ in}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 0.0953 \text{ in}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 0.0953 \text{ in}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.0953$ in

Available nozzle wall thickness new, $t_n = 0.875 \times 0.109 = 0.0954$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The thickness requirements of UG-45 govern the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 307.35 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.0945	0.1514	0.081	0.0548	--	--	0.0156	0.0953	0.0954

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0763	0.0875	weld size is adequate

Calculations for internal pressure 307.35 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.04768).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.1007, 0.5504 + (0.109 - 0) + (0.1875 - 0)) \\
 &= 1.1007 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5 \times (0.1875 - 0), 2.5 \times (0.109 - 0) + 0) \\
 &= 0.2725 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \times R_n / (S_n \times E - 0.6 \times P) \\
 &= 307.351 \times 0.5485 / (20,000 \times 1 - 0.6 \times 307.351)
 \end{aligned}$$

$$= 0.0085 \text{ in}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned} t_r &= P K_1 D / (2 S E - 0.2 P) \\ &= 307.351 \cdot 0.9 \cdot 12.39 / (2 \cdot 20,000 \cdot 1 - 0.2 \cdot 307.351) \\ &= 0.0858 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$

$$\begin{aligned} A &= d t_r F + 2 t_n t_r F (1 - f_{r1}) \\ &= 1.1007 \cdot 0.0858 \cdot 1 + 2 \cdot 0.109 \cdot 0.0858 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.0945} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.081} \text{ in}^2$

$$\begin{aligned} &= d (E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ &= 1.1007 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\ &= 0.081 \text{ in}^2 \\ &= 2 (t + t_n) (E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ &= 2 \cdot (0.1875 + 0.109) \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\ &= 0.0436 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0548} \text{ in}^2$

$$\begin{aligned} &= 5 (t_n - t_m) f_{r2} t \\ &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.1875 \\ &= 0.0942 \text{ in}^2 \\ &= 5 (t_n - t_m) f_{r2} t_n \\ &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.109 \\ &= 0.0548 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 f_{r2} \\ &= 0.125^2 \cdot 1 \\ &= \underline{0.0156} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.081 + 0.0548 + 0.0156 \\ &= \underline{0.1514} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.109 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.0763 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.125 = 0.0875 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1} = 0.0085 \text{ in } (E = 1)$

Wall thickness per UG-45(b)(1): $t_{r2} = 0.0953 \text{ in}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 0.1164 \text{ in}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 0.0953 \text{ in}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 0.0953 \text{ in}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.0953 \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 * 0.109 = 0.0954 \text{ in}$

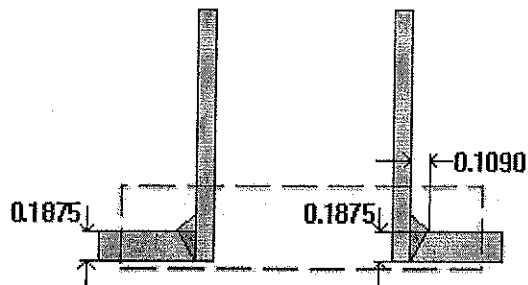
The nozzle neck thickness is adequate.

Gas Outlet (N1)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.109 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Ellipsoidal Head #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	1" Sch 10S
Nozzle orientation:	0°
Calculated as hillside:	no
Local vessel minimum thickness:	0.1875 in
End of nozzle to datum line:	-5.76 in
Nozzle inside diameter, new:	1.097 in
Nozzle nominal wall thickness:	0.109 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.9925 in
Distance to head center, R:	0 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

The thickness requirements of UG-45 govern the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 221.3 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.0941	0.1474	0.0807	0.0548	--	--	0.0119	0.0953	0.0954

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0763	0.0763	weld size is adequate

Calculations for internal pressure 221.3 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.04768).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.097, 0.5485 + (0.109 - 0) + (0.1875 - 0)) \\
 &= 1.097 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.1875 - 0), 2.5*(0.109 - 0) + 0) \\
 &= 0.2725 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 221.2951 \cdot 0.5485 / (14,400 \cdot 1 - 0.6 \cdot 221.2951) \\
 &= 0.0085 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P \cdot K_t \cdot D / (2 \cdot S \cdot E - 0.2 \cdot P) \\
 &= 221.2951 \cdot 0.9 \cdot 12.39 / (2 \cdot 14,400 \cdot 1 - 0.2 \cdot 221.2951) \\
 &= 0.0858 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 1.097 \cdot 0.0858 \cdot 1 + 2 \cdot 0.109 \cdot 0.0858 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.0941 \text{ in}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.0807 \text{ in}^2}$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 1.097 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\
 &= 0.0807 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1875 + 0.109) \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\
 &= 0.0436 \text{ in}^2
 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0548 \text{ in}^2}$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.1875 \\
 &= 0.0942 \text{ in}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.109 \\
 &= 0.0548 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.109^2 \cdot 1 \\
 &= \underline{0.0119 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.0807 + 0.0548 + 0.0119 \\
 &= \underline{0.1474 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.109 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = \underline{0.0763 \text{ in}}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.109 = 0.0763 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1} = 0.0085 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1): $t_{r2} = 0.0953 \text{ in}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 0.1164 \text{ in}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 0.0953 \text{ in}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 0.0953 \text{ in}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.0953$ in

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.109 = 0.0954$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The thickness requirements of UG-45 govern the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 307.35 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.0941	0.1474	0.0807	0.0548	--	--	0.0119	0.0953	0.0954

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg 41)	0.0763	0.0763	weld size is adequate

Calculations for internal pressure 307.35 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.04768).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.097, 0.5485 + (0.109 - 0) + (0.1875 - 0)) \\
 &= 1.097 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.109 - 0) + 0) \\
 &= 0.2725 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 307.351 \cdot 0.5485 / (20,000 \cdot 1 - 0.6 \cdot 307.351)
 \end{aligned}$$

$$= 0.0085 \text{ in}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned} t_r &= P \cdot K_1 \cdot D / (2 \cdot S \cdot E - 0.2 \cdot P) \\ &= 307.351 \cdot 0.9 \cdot 12.39 / (2 \cdot 20,000 \cdot 1 - 0.2 \cdot 307.351) \\ &= 0.0858 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 1.097 \cdot 0.0858 \cdot 1 + 2 \cdot 0.109 \cdot 0.0858 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.0941} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.0807} \text{ in}^2$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 1.097 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\ &= 0.0807 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1875 + 0.109) \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) - 2 \cdot 0.109 \cdot (0.85 \cdot 0.1875 - 1 \cdot 0.0858) \cdot (1 - 1) \\ &= 0.0436 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0548} \text{ in}^2$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.1875 \\ &= 0.0942 \text{ in}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.109 - 0.0085) \cdot 1 \cdot 0.109 \\ &= 0.0548 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.109^2 \cdot 1 \\ &= \underline{0.0119} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.0807 + 0.0548 + 0.0119 \\ &= \underline{0.1474} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.109 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{min} = \underline{0.0763} \text{ in}$

$t_{c(actual)} = 0.7*Leg = 0.7*0.109 = 0.0763 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1} = 0.0085 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1): $t_{r2} = 0.0953 \text{ in}$

Wall thickness per UG-16(b): $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 0.1164 \text{ in}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 0.0953 \text{ in}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 0.0953 \text{ in}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.0953} \text{ in}$

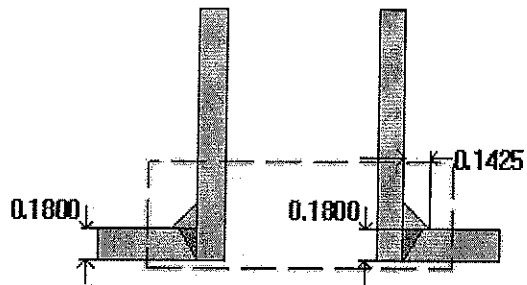
Available nozzle wall thickness new, $t_n = 0.875*0.109 = 0.0954 \text{ in}$

The nozzle neck thickness is adequate.

Thermocouple (N3)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(\text{lower})} = 0.18 \text{ in}$$
$$\text{Leg}_{41} = 0.1425 \text{ in}$$



Note: round inside edges per UG-78(c)

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, In. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	0.500" Class 3000 - threaded
Nozzle orientation:	0°
Local vessel minimum thickness:	0.1575 in
Nozzle center line offset to datum line:	37.5 in
End of nozzle to shell center:	6.625 in
Nozzle inside diameter, new:	0.84 in
Nozzle nominal wall thickness:	0.1425 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.25 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For P = 273.56 psi @ 932 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 273.56 psi @ 932 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_g) \\
 &= \text{MIN}(2.5*(0.1575 - 0), 2.5*(0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 0.42 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\
 &= 273.557 \cdot 6.195 / (14,400 \cdot 1 - 0.6 \cdot 273.557) \\
 &= 0.119 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 14,400$, $S_v = 14,400$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\
 &= \underline{0.1 \text{ in}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 0.0125 in²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0125 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\
 &= 0.0089 \text{ in}^2
 \end{aligned}$$

A_2 = smaller of the following = 0.0672 in²

$$\begin{aligned}
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2 \\
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\
 &= 0.0672 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.1425^2 \cdot 1 \\
 &= \underline{0.0203 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.0125 + 0.0672 + 0.0203 \\
 &= \underline{0.1 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = \underline{0.0997} \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in (E = 1)}$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 \times 0.1425 = 0.1247$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in ²) For P = 379.94 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1	0.1	0.0125	0.0672	--	--	0.0203	0.0625	0.1247

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0997	0.0997	weld size is adequate

Calculations for internal pressure 379.94 psi @ 70 °F

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.02793).

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(0.84, 0.42 + (0.1425 - 0) + (0.1575 - 0)) \\
 &= 0.84 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5 \times (t - C), 2.5 \times (t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5 \times (0.1575 - 0), 2.5 \times (0.1425 - 0) + 0) \\
 &= 0.3563 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_{rn} &= P \times R_n / (S_n \times E - 0.6 \times P) \\
 &= 379.938 \times 0.42 / (20,000 \times 1 - 0.6 \times 379.938) \\
 &= 0.0081 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R / (S \cdot E - 0.6 \cdot P) \\ &= 379.938 \cdot 6.195 / (20,000 \cdot 1 - 0.6 \cdot 379.938) \\ &= 0.119 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 20,000$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 0.84 \cdot 0.119 \cdot 1 + 2 \cdot 0.1425 \cdot 0.119 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0125} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 0.84 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0125 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1575 + 0.1425) \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) - 2 \cdot 0.1425 \cdot (0.85 \cdot 0.1575 - 1 \cdot 0.119) \cdot (1 - 1) \\ &= 0.0089 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.0672} \text{ in}^2$$

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \\ &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1425 - 0.0081) \cdot 1 \cdot 0.25 \\ &= 0.0672 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1425^2 \cdot 1 \\ &= \underline{0.0203} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.0125 + 0.0672 + 0.0203 \\ &= \underline{0.1} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1425 \text{ in}$

$t_{c(min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{min} = \underline{0.0997} \text{ in}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 0.1425 = 0.0998 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1: $t_{r1} = 0.0106 \text{ in } (E = 1)$

Wall thickness per UG-16(b): $t_{r3} = \underline{0.0625} \text{ in}$

Available nozzle wall thickness new, $t_n = 0.875 * 0.1425 = 0.1247 \text{ in}$

The nozzle neck thickness is adequate.

Geometry

Height(radial): 1"
Width (circumferential): 1"
Length 0.5"
Fillet Weld Size: 0.25"
Location Angle: 30.00°

Applied Loads

Radial load: $P_r = 0$ lb_f
Circumferential moment: $M_c = 0$ lb_f-in
Circumferential shear: $V_c = 0$ lb_f
Longitudinal moment: $M_L = 0$ lb_f-in
Longitudinal shear: $V_L = 1,500$ lb_f
Torsion moment: $M_t = 0$ lb_f-in
Internal pressure: $P = 165$ psi
Mean shell radius: $R_m = 6.2738$ in
Shell yield stress: $S_y = 16,000$ psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

$$R_m / t = 6.2738 / 0.1575 = 39.8333$$

$$C_1 = 0.75, C_2 = 0.5 \text{ in}$$

$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 6,490 \text{ psi}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i / 2t = 3,245 \text{ psi}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 10,062 \text{ psi}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = +3 \cdot S = +43,200 \text{ psi}$$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 6,490 \text{ psi}$$

$$\text{Allowable local primary membrane } (P_L) = +1.5 \cdot S = +21,600 \text{ psi}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	6.227	0.0961	0	0	0	0	0	0	0	0
4C*	6.8235	0.1087	0	0	0	0	0	0	0	0
1C	0.1203	0.11	0	0	0	0	0	0	0	0
2C-1	0.0841	0.11	0	0	0	0	0	0	0	0
3A*	1.2927	0.1044	0	0	0	0	0	0	0	0
1A	0.0929	0.1201	0	0	0	0	0	0	0	0
3B*	3.9969	0.0912	0	0	0	0	0	0	0	0
1B-1	0.0476	0.0958	0	0	0	0	0	0	0	0
Pressure stress*			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
Total circumferential stress			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
Primary membrane circumferential stress*			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
3C*	5.8998	0.1067	0	0	0	0	0	0	0	0
4C*	6.9932	0.0961	0	0	0	0	0	0	0	0
1C-1	0.1298	0.1009	0	0	0	0	0	0	0	0
2C	0.0904	0.1009	0	0	0	0	0	0	0	0
4A*	1.8401	0.1044	0	0	0	0	0	0	0	0
2A	0.0521	0.1103	0	0	0	0	0	0	0	0
4B*	1.0996	0.0912	0	0	0	0	0	0	0	0
2B-1	0.0754	0.0955	0	0	0	0	0	0	0	0
Pressure stress*			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Total longitudinal stress			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Primary membrane longitudinal stress*			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Shear from M_t			0	0	0	0	0	0	0	0

Circ shear from V_c	0	0	0	0	0	0	0	0
Long shear from V_L	0	0	0	0	-4,762	-4,762	4,762	4,762
Total Shear stress	0	0	0	0	-4,762	-4,762	4,762	4,762
Combined stress (P_L+P_D+Q)	6,490	6,490	6,490	6,490	10,062	10,062	10,062	10,062

Note: * denotes primary stress.

Geometry

Height(radial): 1"
Width (circumferential): 1"
Length 0.5"
Fillet Weld Size: 0.25"
Location Angle: 150.00°

Applied Loads

Radial load: $P_r = 0$ lb_f
Circumferential moment: $M_o = 0$ lb_f-in
Circumferential shear: $V_o = 0$ lb_f
Longitudinal moment: $M_L = 0$ lb_f-in
Longitudinal shear: $V_L = 1,500$ lb_f
Torsion moment: $M_t = 0$ lb_f-in
Internal pressure: $P = 165$ psi
Mean shell radius: $R_m = 6.2738$ in
Shell yield stress: $S_y = 16,000$ psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

$$R_m / t = 6.2738 / 0.1575 = 39.8333$$

$$C_1 = 0.75, C_2 = 0.5 \text{ in}$$

$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 6,490 \text{ psi}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i / 2t = 3,245 \text{ psi}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 10,062 \text{ psi}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 43,200 \text{ psi}$$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 6,490 \text{ psi}$$

$$\text{Allowable local primary membrane } (P_L) = \pm 1.5 \cdot S = \pm 21,600 \text{ psi}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	6.227	0.0961	0	0	0	0	0	0	0	0
4C*	6.8235	0.1087	0	0	0	0	0	0	0	0
1C	0.1203	0.11	0	0	0	0	0	0	0	0
2C-1	0.0841	0.11	0	0	0	0	0	0	0	0
3A*	1.2927	0.1044	0	0	0	0	0	0	0	0
1A	0.0929	0.1201	0	0	0	0	0	0	0	0
3B*	3.9969	0.0912	0	0	0	0	0	0	0	0
1B-1	0.0476	0.0958	0	0	0	0	0	0	0	0
Pressure stress*			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
Total circumferential stress			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
Primary membrane circumferential stress*			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
3C*	5.8998	0.1087	0	0	0	0	0	0	0	0
4C*	6.9932	0.0961	0	0	0	0	0	0	0	0
1C-1	0.1298	0.1009	0	0	0	0	0	0	0	0
2C	0.0904	0.1009	0	0	0	0	0	0	0	0
4A*	1.8401	0.1044	0	0	0	0	0	0	0	0
2A	0.0521	0.1103	0	0	0	0	0	0	0	0
4B*	1.0996	0.0912	0	0	0	0	0	0	0	0
2B-1	0.0754	0.0955	0	0	0	0	0	0	0	0
Pressure stress*			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Total longitudinal stress			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Primary membrane longitudinal stress*			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Shear from M_t			0	0	0	0	0	0	0	0

Circ shear from V_c	0	0	0	0	0	0	0	0
Long shear from V_L	0	0	0	0	-4,762	-4,762	4,762	4,762
Total Shear stress	0	0	0	0	-4,762	-4,762	4,762	4,762
Combined stress (P_L+P_D+Q)	6,490	6,490	6,490	6,490	10,062	10,062	10,062	10,062

Note: * denotes primary stress.

Geometry

Height(radial): 1"
Width (circumferential): 1"
Length 0.5"
Fillet Weld Size: 0.25"
Location Angle: 270.00°

Applied Loads

Radial load: $P_r = 0$ lb_f
Circumferential moment: $M_c = 0$ lb_f-in
Circumferential shear: $V_c = 0$ lb_f
Longitudinal moment: $M_L = 0$ lb_f-in
Longitudinal shear: $V_L = 1,500$ lb_f
Torsion moment: $M_t = 0$ lb_f-in
Internal pressure: $P = 165$ psi
Mean shell radius: $R_m = 6.2738$ in
Shell yield stress: $S_y = 16,000$ psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

$$R_m / t = 6.2738 / 0.1575 = 39.8333$$

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$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 6,490 \text{ psi}$$

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$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 43,200 \text{ psi}$$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 6,490 \text{ psi}$$

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Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	6.227	0.0961	0	0	0	0	0	0	0	0
4C*	6.8235	0.1087	0	0	0	0	0	0	0	0
1C	0.1203	0.11	0	0	0	0	0	0	0	0
2C-1	0.0841	0.11	0	0	0	0	0	0	0	0
3A*	1.2927	0.1044	0	0	0	0	0	0	0	0
1A	0.0929	0.1201	0	0	0	0	0	0	0	0
3B*	3.9969	0.0912	0	0	0	0	0	0	0	0
1B-1	0.0476	0.0958	0	0	0	0	0	0	0	0
Pressure stress*			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
Total circumferential stress			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
Primary membrane circumferential stress*			6,490	6,490	6,490	6,490	6,490	6,490	6,490	6,490
3C*	5.8998	0.1087	0	0	0	0	0	0	0	0
4C*	6.9932	0.0961	0	0	0	0	0	0	0	0
1C-1	0.1298	0.1009	0	0	0	0	0	0	0	0
2C	0.0904	0.1009	0	0	0	0	0	0	0	0
4A*	1.8401	0.1044	0	0	0	0	0	0	0	0
2A	0.0521	0.1103	0	0	0	0	0	0	0	0
4B*	1.0996	0.0912	0	0	0	0	0	0	0	0
2B-1	0.0754	0.0955	0	0	0	0	0	0	0	0
Pressure stress*			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Total longitudinal stress			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Primary membrane longitudinal stress*			3,245	3,245	3,245	3,245	3,245	3,245	3,245	3,245
Shear from M_t			0	0	0	0	0	0	0	0

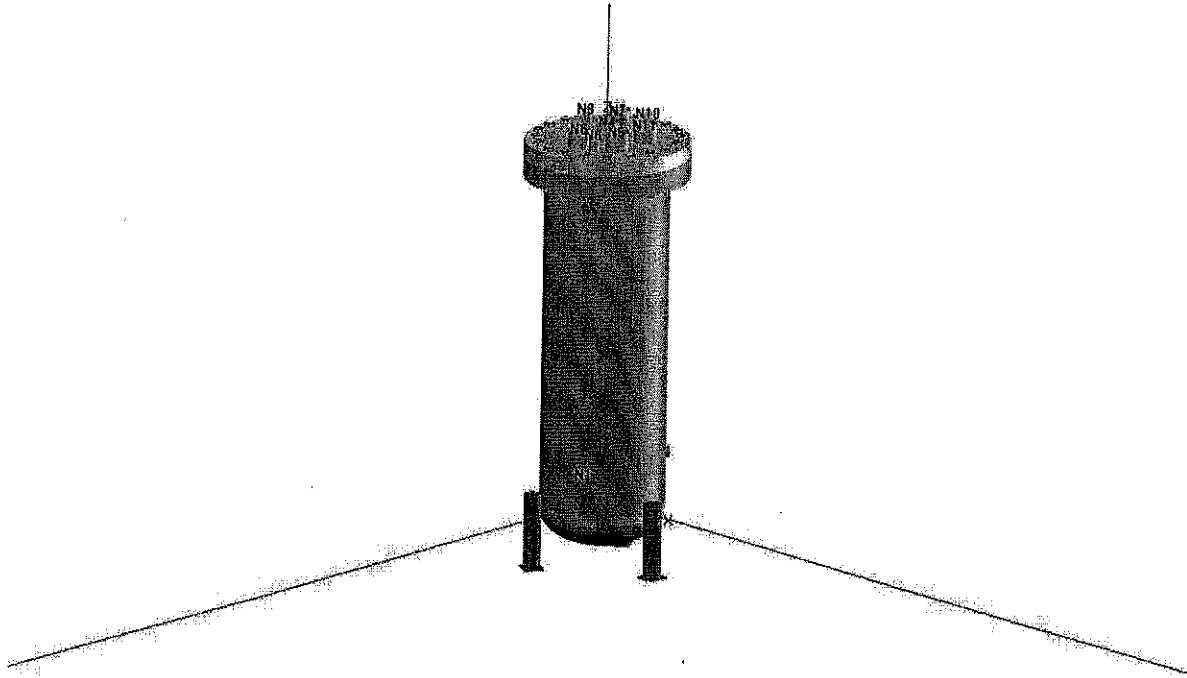
Circ shear from V_c	0	0	0	0	0	0	0	0
Long shear from V_L	0	0	0	0	-4,762	-4,762	4,762	4,762
Total Shear stress	0	0	0	0	-4,762	-4,762	4,762	4,762
Combined stress (P_L+P_b+Q)	6,490	6,490	6,490	6,490	10,062	10,062	10,062	10,062

Note: * denotes primary stress.

EDEN CRYOGENICS, LLC

8445 RAUSCH DRIVE

PLAIN CITY, OHIO 43064



Vessel Design Calculations

Item: VACUUM VESSEL

Vessel No: 2

Customer: FERMI NATIONAL LABORATORY

Contract: BC02128

Designer: ALLAN HANSON

Date: OCTOBER 22, 2009

Location: FERMI NATIONAL LABORATORY

Purchaser: TERRY TOPE

Vessel Name: Vacuum Vessel 12 11 09

Service: VACUUM

P.O. Number: BC02128

Deficiencies Summary

Warnings Summary

Warnings for Copy of Copy of Nozzle #1 (N10)

Overlapping limits of reinforcement between nozzles N10 and N7 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N10 and N11 detected - user intervention may be required.
(warning)

Warnings for Copy of Copy of Nozzle #1 (N9)

Overlapping limits of reinforcement between nozzles N9 and N7 detected - user intervention may be required.
(warning)

Warnings for Copy of Copy of Nozzle #4 (N11)

Overlapping limits of reinforcement between nozzles N11 and N4 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N11 and N5 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N11 and N10 detected - user intervention may be required.
(warning)

Warnings for Copy of Copy of Nozzle #4 (N7)

Overlapping limits of reinforcement between nozzles N7 and N4 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N7 and N9 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N7 and N10 detected - user intervention may be required.
(warning)

Warnings for Copy of Nozzle #1 (N8)

Overlapping limits of reinforcement between nozzles N8 and N5 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N8 and N6 detected - user intervention may be required.
(warning)

Warnings for Copy of Nozzle #4 (N5)

Overlapping limits of reinforcement between nozzles N5 and N4 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N5 and N6 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N5 and N8 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N5 and N11 detected - user intervention may be required.
(warning)

Warnings for Copy of Nozzle #4 (N6)

Overlapping limits of reinforcement between nozzles N6 and N4 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N6 and N5 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N6 and N8 detected - user intervention may be required.
(warning)

Warnings for Nozzle #4 (N4)

Overlapping limits of reinforcement between nozzles N4 and N5 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N4 and N6 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N4 and N7 detected - user intervention may be required.
(warning)

Overlapping limits of reinforcement between nozzles N4 and N11 detected - user intervention may be required.
(warning)

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
<u>N1</u>	Nozzle #1	1.75 IDx0.13	SA-240 304L	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N10</u>	Copy of Copy of Nozzle #1	1.73 IDx0.13	SA-240 304L	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N11</u>	Copy of Copy of Nozzle #4	4" Sch 40S (Std)	SA-312 TP304 Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N2</u>	Copy of Nozzle #1	1.75 IDx0.13	SA-240 304L	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N3</u>	Copy of Nozzle #1	1.75 IDx0.13	SA-240 304L	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N4</u>	Nozzle #4	4" Sch 40S (Std)	SA-312 TP304 Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N5</u>	Copy of Nozzle #4	4" Sch 40S (Std)	SA-312 TP304 Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N6</u>	Copy of Nozzle #4	4" Sch 40S (Std)	SA-312 TP304 Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N7</u>	Copy of Copy of Nozzle #4	4" Sch 40S (Std)	SA-312 TP304 Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N8</u>	Copy of Nozzle #1	1.73 IDx0.13	SA-240 304L	No	No	No	N/A	N/A	N/A	N/A	N/A
<u>N9</u>	Copy of Copy of Nozzle #1	1.73 IDx0.13	SA-240 304L	No	No	No	N/A	N/A	N/A	N/A	N/A

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A ₁ ?	A ₂ ?	Shell			Reinforcement Pad		Corr (in)	A _a /A _r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
<u>N1</u>	2	0.125	0.0625	Yes	Yes	0.25	0.2017		N/A	N/A	0	100.0
<u>N10</u>	2	0.1347	0.1347	Yes	Yes	2.75*	2.4015		N/A	N/A	0	100.0
<u>N11</u>	4.5	0.237	0.237	Yes	Yes	2.75*	2.0862		N/A	N/A	0	100.0
<u>N2</u>	2	0.125	0.0625	Yes	Yes	0.25	0.2017		N/A	N/A	0	100.0
<u>N3</u>	2	0.125	0.0625	Yes	Yes	0.25	0.2017		N/A	N/A	0	100.0
<u>N4</u>	4.5	0.237	0.237	Yes	Yes	2.75*	2.0862		N/A	N/A	0	100.0
<u>N5</u>	4.5	0.237	0.237	Yes	Yes	2.75*	2.0862		N/A	N/A	0	100.0
<u>N6</u>	4.5	0.237	0.237	Yes	Yes	2.75*	2.0862		N/A	N/A	0	100.0
<u>N7</u>	4.5	0.237	0.237	Yes	Yes	2.75*	2.0862		N/A	N/A	0	100.0
<u>N8</u>	2	0.1347	0.1347	Yes	Yes	2.75*	2.4015		N/A	N/A	0	100.0
<u>N9</u>	2	0.1347	0.1347	Yes	Yes	2.75*	2.4015		N/A	N/A	0	100.0

t_n : Nozzle thickness

Req t_n : Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a: Area available per UG-37, governing condition

A_r: Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

* Head minimum thickness after forming

Pressure Summary

Pressure Summary for Chamber bounded by Bottom Ellipsoidal Head and Bolted Cover #1

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T _e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
<u>Bolted Cover #1</u>	0	932	295.38	465.37	631.83	100	-320	Note 1	No
<u>Vacuum Vessel Shell</u>	0	932	265.12	368.23	69.13	100	-320	Note 1	No
<u>Straight Flange on Bottom Ellipsoidal Head</u>	0	932	265.12	368.23	69.13	100	-320	Note 1	No
<u>Bottom Ellipsoidal Head</u>	0	932	229.42	318.64	82.82	100	-320	Note 2	No
<u>Leas #1</u>	0	932	0	N/A	N/A	N/A	N/A	N/A	N/A
<u>Flange #1</u>	0	932	235.89	542.88	2,046.96	100	-320	Note 1	No
<u>Nozzle #1 (N1)</u>	0	932	N/A	N/A	56.26	100	N/A	N/A	No
<u>Copy of Copy of Nozzle #1 (N10)</u>	0	932	N/A	N/A	481.85	100	N/A	N/A	No
<u>Copy of Copy of Nozzle #4 (N11)</u>	0	932	N/A	N/A	363.62	100	N/A	N/A	No
<u>Copy of Nozzle #1 (N2)</u>	0	932	N/A	N/A	56.26	100	N/A	N/A	No
<u>Copy of Nozzle #1 (N3)</u>	0	932	N/A	N/A	56.26	100	N/A	N/A	No
<u>Nozzle #4 (N4)</u>	0	932	N/A	N/A	363.62	100	N/A	N/A	No
<u>Copy of Nozzle #4 (N5)</u>	0	932	N/A	N/A	363.62	100	N/A	N/A	No
<u>Copy of Nozzle #4 (N6)</u>	0	932	N/A	N/A	363.62	100	N/A	N/A	No
<u>Copy of Copy of Nozzle #4 (N7)</u>	0	932	N/A	N/A	363.62	100	N/A	N/A	No
<u>Copy of Nozzle #1 (N8)</u>	0	932	N/A	N/A	481.85	100	N/A	N/A	No
<u>Copy of Copy of Nozzle #1 (N9)</u>	0	932	N/A	N/A	481.85	100	N/A	N/A	No

Chamber design MDMT is -320 °F

Chamber rated MDMT is -320 °F @ 0 psi

Chamber MAWP hot & corroded is 0 psi @ 932 °F

Chamber MAP cold & new is 318.64 psi @ 70 °F

Chamber MAEP is 56.26 psi @ 100 °F

Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Rated MDMT per UHA-51(d)(1)(a) = -320 °F	
2.	Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F	

Design notes are available on the Settings Summary page.

Revision History

No.	Date	Operator	Notes
0	10/21/2009	ahanson	New vessel created ASME Section VIII Division 1 [Build 6263]

Settings Summary

COMPRESS Build 6263

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	0.0625" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	1"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials $> 1.25\text{"}\text{ and } \leq 1.50\text{"}\text{ thick:}$	No
UG-37(a) shell tr calculation considers longitudinal stress:	No
Butt welds are tapered per Figure UCS-66.3(a).	

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times vessel MAWP
Test liquid specific gravity:	1.00
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116 (e) Radiography:	RT1
UG-116 (f) Postweld heat treatment:	None

Code Cases/Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	Yes
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	Yes
Apply interpretation VIII-1-01-37:	Yes
No UCS-66.1 MDMT reduction:	No
No UCS-68(c) MDMT reduction:	No
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

UG-22 (a) Internal or External Design Pressure :	Yes
UG-22 (b) Weight of the vessel and normal contents under operating or test conditions:	Yes
UG-22 (c) Superimposed static reactions from weight of attached equipment (external loads):	No
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22 (f) Wind reactions:	No
UG-22 (f) Seismic reactions:	No

Note: UG-22 (b),(c) and (f) loads only considered when supports are present.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
<u>Bolted Cover #1</u>	SA-240 304L	32 OD	2.75	2.75*	1.3744	0	1.00	External
<u>Vacuum Vessel Shell</u>	SA-312 TP304 Wld & smls pipe	23.5 ID	62.22	0.25	0.1192	0	1.00	External
<u>Straight Flange on Bottom Ellipsoidal Head</u>	SA-312 TP304 Wld & smls pipe	23.5 ID	1.5	0.25	0.1192	0	1.00	External
<u>Bottom Ellipsoidal Head</u>	SA-312 TP304 Wld & smls pipe	23.5 ID	6.0625	0.1875*	0.0619	0	1.00	External

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements							Surface Area ft ²
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid	
<u>Bolted Cover #1</u>	570.5	570.5	0	0	0	0	8.3	7
<u>Vacuum Vessel Shell</u>	335.9	335.9	0	0	0	0	981.1	33
<u>Bottom Ellipsoidal Head</u>	43.4	43.4	0	0	0	0	84.8	6
<u>Legs #1</u>	30.7	30.7	0	0	0	0	0	4
TOTAL:	980.4	980.4	0	0	0	0	1,074.2	49

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (lb) Contributed by Attachments									Surface Area ft²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads	
	New	Corroded	New	Corroded						
<u>Bolted Cover #1</u>	0	0	31.7	31.7	0	0	0	0	0	2
<u>Vacuum Vessel Shell</u>	413.3	413.3	1.5	1.5	0	0	0	0	0	10
<u>Bottom Ellipsoidal Head</u>	0	0	0	0	0	0	0	0	0	0
<u>Legs #1</u>	0	0	0	0	0	0	0	0	0	0
TOTAL:	413.3	413.3	33.2	33.2	0	0	0	0	0	2

Vessel operating weight, Corroded: 1,427 lb

Vessel operating weight, New: 1,427 lb

Vessel empty weight, Corroded: 1,427 lb

Vessel empty weight, New: 1,427 lb

Vessel test weight, New: 2,501 lb

Vessel surface area: 51 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 1,427 lb

Center of Gravity: 51.6114"

Vessel Capacity

Vessel Capacity** (New): 127 US gal

Vessel Capacity** (Corroded): 127 US gal

**The vessel capacity does not include volume of nozzle, piping or other attachments.

Hydrostatic Test

Shop test pressure determination for Chamber bounded by Bottom Ellipsoidal Head and Bolted Cover #1 based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 101.59 psi at 70 °F (the chamber MAEP = 56.265 psi). External pressure governs the test pressure per UG-99(f).

The shop test is performed with the vessel in the horizontal position.

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Vacuum Vessel Shell (1)	102.438	0.848	1.3889	1.30	5,553	27,000	No
Straight Flange on Bottom Ellipsoidal Head	102.438	0.848	1.3889	1.30	5,553	27,000	No
Bottom Ellipsoidal Head	102.438	0.848	1.3889	1.30	5,778	27,000	No
Bolted Cover #1	102.438	0.848	1.5755	1.30	3,676	33,750	No
Flange #1	102.438	0.848	1.5755	1.30	6,302	33,750	No
Copy of Copy of Nozzle #1 (N10)	101.986	0.396	1.5755	1.30	NI	NI	NI
Copy of Copy of Nozzle #1 (N9)	102.368	0.778	1.5755	1.30	NI	NI	NI
Copy of Copy of Nozzle #4 (N11)	101.851	0.261	1.3889	1.30	NI	NI	NI
Copy of Copy of Nozzle #4 (N7)	102.231	0.641	1.3889	1.30	NI	NI	NI
Copy of Nozzle #1 (N2)	102.484	0.893	1.5755	1.30	7,699	33,750	No
Copy of Nozzle #1 (N3)	101.825	0.235	1.5755	1.30	7,649	33,750	No
Copy of Nozzle #1 (N8)	101.874	0.284	1.5755	1.30	NI	NI	NI
Copy of Nozzle #4 (N5)	101.851	0.261	1.3889	1.30	NI	NI	NI
Copy of Nozzle #4 (N6)	102.087	0.497	1.3889	1.30	NI	NI	NI
Nozzle #1 (N1)	101.825	0.235	1.5755	1.30	7,649	33,750	No
Nozzle #4 (N4)	102.087	0.497	1.3889	1.30	NI	NI	NI

Notes:

- (1) Vacuum Vessel Shell limits the UG-99 stress ratio.
- (2) NI indicates that test stress was not investigated.
- (3) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
- (4) VIII-2, AD-151.1(b) used as the basis for nozzle allowable test stress.
- (5) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Bottom Ellipsoidal Head and Bolted Cover #1.

Vacuum Summary

Component	Line of Support	Elevation above Datum (In)	Length Le (In)
<u>Bolted Cover #1</u>	-	65.395	N/A
-	<u>1/3 depth of Bolted Cover #1</u>	62.645	N/A
<u>Vacuum Vessel Shell Top</u>	-	62.22	66.1033
<u>Vacuum Vessel Shell Bottom</u>	-	0	66.1033
<u>Straight Flange on Bottom Ellipsoidal Head Top</u>	-	0	66.1033
<u>Straight Flange on Bottom Ellipsoidal Head Bottom</u>	-	-1.5	66.1033
-	<u>1/3 depth of Bottom Ellipsoidal Head</u>	-3.4583	N/A
<u>Bottom Ellipsoidal Head</u>	-	-7.5625	N/A

Note
For main components, the listed value of 'Le' is the largest unsupported length for the component.

Vacuum Vessel Shell

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Component: Cylinder
Material specification: SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Pipe NPS and Schedule: 24" Sch 10S
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 0$ psi @ 932 °F
External design pressure: $P_e = 15$ psi @ 100 °F

Static liquid head:

$P_{th} = 0.85$ psi (SG = 1, $H_s = 23.5$ ", Horizontal test head)

Corrosion allowance Inner C = 0" Outer C = 0"

Design MDMT = -320 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - Full UW-11(a) Type 1
Top circumferential joint - N/A
Bottom circumferential joint - Full UW-11(a) Type 1

Estimated weight New = 336.6 lb corr = 336.6 lb
Capacity New = 116.83 US gal corr = 116.83 US gal

ID = 23.5"
Length L_o = 62.22"
 t = 0.25"

Maximum allowable working pressure, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) - P_s \\ &= 14,400 \cdot 1.00 \cdot 0.2188 / (11.75 + 0.60 \cdot 0.2188) - 0 \\ &= 265.12 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) \\ &= 20,000 \cdot 1.00 \cdot 0.2188 / (11.75 + 0.60 \cdot 0.2188) \\ &= 368.23 \text{ psi} \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$L / D_o = 66.1033 / 24 = 2.7543$
 $D_o / t = 24 / 0.1192 = 201.3703$
From table G: A = 0.000161
From table HA-1: B = 2,265 psi

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\ &= 4 \cdot 2265.4226 / (3 \cdot (24 / 0.1192)) \end{aligned}$$

$$= 15 \text{ psi}$$

Design thickness for external pressure $P_a = 15 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.1192 + 0 = 0.1192"$$

Maximum Allowable External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 66.1033 / 24 = 2.7543$$

$$D_o / t = 24 / 0.2188 = 109.7143$$

$$\text{From table G: } A = 0.000405$$

$$\text{From table HA-1: } B = 5,689 \text{ psi}$$

$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*5688.6738 / (3*(24 / 0.2188)) \\ &= 69.13 \text{ psi} \end{aligned}$$

External Pressure + Weight Check (Bergman, ASME paper 54-A-104)

$$\begin{aligned} P_v &= W / (2*\pi*R_m) + M / (\pi*R_m^2) \\ &= 1,419.1 / (2*\pi*11.875) + 47 / (\pi*11.875^2) \\ &= 19.1252 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} \alpha &= P_v / (P_g*D_o) \\ &= 19.1252 / (15*24) \\ &= 0.0531 \end{aligned}$$

$$n = 3$$

$$\begin{aligned} m &= 1.23 / (L / D_o)^2 \\ &= 1.23 / (66.1033 / 24)^2 \\ &= 0.1621 \end{aligned}$$

$$\begin{aligned} \text{Ratio } P_g &= (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m) \\ &= (3^2 - 1 + 0.1621 + 0.1621*0.0531) / (3^2 - 1 + 0.1621) \\ &= 1.0011 \end{aligned}$$

Ratio $P_g * P_a \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight Check at Bottom Seam (Bergman, ASME paper 54-A-104)

$$\begin{aligned} P_v &= W / (2*\pi*R_m) + M / (\pi*R_m^2) \\ &= 1,419.1 / (2*\pi*11.875) + 0 / (\pi*11.875^2) \\ &= 19.0195 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} \alpha &= P_v / (P_g*D_o) \\ &= 19.0195 / (15*24) \\ &= 0.0528 \end{aligned}$$

$$n = 3$$

$$\begin{aligned} m &= 1.23 / (L / D_o)^2 \\ &= 1.23 / (66.1033 / 24)^2 \\ &= 0.1621 \end{aligned}$$

$$\text{Ratio } P_g = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$$

$$= (3^2 - 1 + 0.1621 + 0.1621 \cdot 0.0528) / (3^2 - 1 + 0.1621)$$

$$= 1.0010$$

Ratio $P_e \cdot P_o \leq$ MAEP design cylinder thickness is satisfactory.

Design thickness = 0.1192"

The governing condition is due to external pressure.

The cylinder thickness of 0.25" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S _t	S _c						
<u>Operating, Hot & Corroded</u>	0	14,400	<u>5,750</u>	932	0	Top	Weight	<u>0.0033</u>	<u>0.0033</u>
						Bottom	Weight	<u>0.0033</u>	<u>0.0033</u>
<u>Operating, Hot & New</u>	0	14,400	<u>5,750</u>	932	0	Top	Weight	<u>0.0033</u>	<u>0.0033</u>
						Bottom	Weight	<u>0.0033</u>	<u>0.0033</u>
<u>Hot Shut Down, Corroded</u>	0	14,400	<u>5,750</u>	932	0	Top	Weight	<u>0.0033</u>	<u>0.0033</u>
						Bottom	Weight	<u>0.0033</u>	<u>0.0033</u>
<u>Hot Shut Down, New</u>	0	14,400	<u>5,750</u>	932	0	Top	Weight	<u>0.0033</u>	<u>0.0033</u>
						Bottom	Weight	<u>0.0033</u>	<u>0.0033</u>
<u>Empty, Corroded</u>	0	20,000	<u>11,813</u>	70	0	Top	Weight	<u>0.0016</u>	<u>0.0016</u>
						Bottom	Weight	<u>0.0016</u>	<u>0.0016</u>
<u>Empty, New</u>	0	20,000	<u>11,813</u>	70	0	Top	Weight	<u>0.0016</u>	<u>0.0016</u>
						Bottom	Weight	<u>0.0016</u>	<u>0.0016</u>
<u>Vacuum</u>	-15	20,000	<u>11,813</u>	100	0	Top	Weight	<u>0.0091</u>	<u>0.0091</u>
						Bottom	Weight	<u>0.0091</u>	<u>0.0091</u>
<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only</u>	0	14,400	<u>5,750</u>	932	0	Top	Weight	<u>0.0033</u>	<u>0.0033</u>
						Bottom	Weight	<u>0.0033</u>	<u>0.0033</u>

Allowable Compressive Stress, Hot and Corroded- S_{CHC} (table HA-1)

$$A = 0.125 / (R_o / t)$$

$$= 0.125 / (12 / 0.2188)$$

$$= 0.002279$$

$$B = 5,750 \text{ psi}$$

$$S = 14,400 / 1.00 = 14,400 \text{ psi}$$

$$S_{CHC} = \min(B, S) = \underline{5,750 \text{ psi}}$$

Allowable Compressive Stress, Hot and New- S_{CHN}

$$S_{CHN} = S_{CHC}$$

$$= \underline{5,750 \text{ psi}}$$

Allowable Compressive Stress, Cold and New- S_{cCN} , (table HA-1)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (12 / 0.2188) \\
 &= 0.002279 \\
 B &= 11,813 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cCN} &= \min(B, S) = \underline{11,813 \text{ psi}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$\begin{aligned}
 S_{cCC} &= S_{cCN} \\
 &= \underline{11,813 \text{ psi}}
 \end{aligned}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC} , (table HA-1)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (12 / 0.2188) \\
 &= 0.002279 \\
 B &= 11,813 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cVC} &= \min(B, S) = \underline{11,813 \text{ psi}}
 \end{aligned}$$

Operating, Hot & Corroded, Above Support Point

$$\begin{aligned}
 t_p &= P \cdot R / (2 \cdot S_c \cdot K_s + 0.40 \cdot |P|) && \text{(Pressure)} \\
 &= 0 \cdot 11.75 / (2 \cdot 5,750.24 \cdot 1.00 + 0.40 \cdot |0|) \\
 &= 0"
 \end{aligned}$$

$$\begin{aligned}
 t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\
 &= 47 / (\pi \cdot 11.875^2 \cdot 5,750.24 \cdot 1.00) \\
 &= 0"
 \end{aligned}$$

$$\begin{aligned}
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) && \text{(Weight)} \\
 &= 1,419.1 / (2 \cdot \pi \cdot 11.875 \cdot 5,750.24 \cdot 1.00) \\
 &= 0.0033"
 \end{aligned}$$

$$\begin{aligned}
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |0 + 0 - (0.0033)| \\
 &= \underline{0.0033"}
 \end{aligned}$$

$$\begin{aligned}
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0 + (0.0033) - (0) \\
 &= \underline{0.0033"}
 \end{aligned}$$

Maximum allowable working pressure, Longitudinal Stress

$$\begin{aligned}
 P &= 2 \cdot S_t \cdot K_s \cdot E_o \cdot (t - t_m + t_w) / (R - 0.40 \cdot (t - t_m + t_w)) \\
 &= 2 \cdot 14,400 \cdot 1.00 \cdot 1.00 \cdot (0.2188 - 0 + (0.0013)) / (11.75 - 0.40 \cdot (0.2188 - 0 + (0.0013))) \\
 &= 543.46 \text{ psi}
 \end{aligned}$$

Operating, Hot & New, Above Support Point

$$\begin{aligned}t_p &= P \cdot R / (2 \cdot S_c \cdot K_s + 0.40 \cdot |P|) && \text{(Pressure)} \\&= 0 \cdot 11.75 / (2 \cdot 5,750.24 \cdot 1.00 + 0.40 \cdot |0|) \\&= 0''\end{aligned}$$

$$\begin{aligned}t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\&= 47 / (\pi \cdot 11.875^2 \cdot 5,750.24 \cdot 1.00) \\&= 0''\end{aligned}$$

$$\begin{aligned}t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) && \text{(Weight)} \\&= 1,419.1 / (2 \cdot \pi \cdot 11.875 \cdot 5,750.24 \cdot 1.00) \\&= 0.0033''\end{aligned}$$

$$\begin{aligned}t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\&= |0 + 0 - (0.0033)| \\&= \underline{0.0033''}\end{aligned}$$

$$\begin{aligned}t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\&= 0 + (0.0033) - (0) \\&= \underline{0.0033''}\end{aligned}$$

Maximum allowable working pressure, Longitudinal Stress

$$\begin{aligned}P &= 2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w) / (R - 0.40 \cdot (t - t_m + t_w)) \\&= 2 \cdot 14,400 \cdot 1.00 \cdot 1.00 \cdot (0.2188 - 0 + (0.0013)) / (11.75 - 0.40 \cdot (0.2188 - 0 + (0.0013))) \\&= 543.46 \text{ psi}\end{aligned}$$

Hot Shut Down, Corroded, Above Support Point

$$\begin{aligned}t_p &= 0'' && \text{(Pressure)} \\t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\&= 47 / (\pi \cdot 11.875^2 \cdot 5,750.24 \cdot 1.00) \\&= 0''\end{aligned}$$

$$\begin{aligned}t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) && \text{(Weight)} \\&= 1,419.1 / (2 \cdot \pi \cdot 11.875 \cdot 5,750.24 \cdot 1.00) \\&= 0.0033''\end{aligned}$$

$$\begin{aligned}t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\&= |0 + 0 - (0.0033)| \\&= \underline{0.0033''}\end{aligned}$$

$$\begin{aligned}t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\&= 0 + (0.0033) - (0) \\&= \underline{0.0033''}\end{aligned}$$

Hot Shut Down, New, Above Support Point

$$\begin{aligned}t_p &= 0'' && \text{(Pressure)} \\t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\&= 47 / (\pi \cdot 11.875^2 \cdot 5,750.24 \cdot 1.00) \\&= 0''\end{aligned}$$

$$t_w = W / (2\pi R_m S_c K_s) \quad (\text{Weight})$$

$$= 1,419.1 / (2\pi 11.875^2 5,750.24 \cdot 1.00)$$

$$= 0.0033"$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0 + 0 - (0.0033)|$$

$$= 0.0033"$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0 + (0.0033) - (0)$$

$$= 0.0033"$$

Empty. Corroded. Above Support Point

$$t_p = 0" \quad (\text{Pressure})$$

$$t_m = M / (\pi R_m^2 S_c K_s) \quad (\text{bending})$$

$$= 47 / (\pi 11.875^2 11,812.64 \cdot 1.00)$$

$$= 0"$$

$$t_w = W / (2\pi R_m S_c K_s) \quad (\text{Weight})$$

$$= 1,419.1 / (2\pi 11.875^2 11,812.64 \cdot 1.00)$$

$$= 0.0016"$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0 + 0 - (0.0016)|$$

$$= 0.0016"$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0 + (0.0016) - (0)$$

$$= 0.0016"$$

Empty. New. Above Support Point

$$t_p = 0" \quad (\text{Pressure})$$

$$t_m = M / (\pi R_m^2 S_c K_s) \quad (\text{bending})$$

$$= 47 / (\pi 11.875^2 11,812.64 \cdot 1.00)$$

$$= 0"$$

$$t_w = W / (2\pi R_m S_c K_s) \quad (\text{Weight})$$

$$= 1,419.1 / (2\pi 11.875^2 11,812.64 \cdot 1.00)$$

$$= 0.0016"$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0 + 0 - (0.0016)|$$

$$= 0.0016"$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0 + (0.0016) - (0)$$

$$= 0.0016"$$

Vacuum. Above Support Point

$$t_p = P \cdot R / (2 S_c K_s + 0.40 |P|) \quad (\text{Pressure})$$

$$= -15 \cdot 11.75 / (2 \cdot 11,812.64 \cdot 1.00 + 0.40 \cdot |15|)$$

$$= -0.0075"$$

$$\begin{aligned} t_m &= M / (\pi R_m^2 S_c K_s) && \text{(bending)} \\ &= 47 / (\pi 11.875^2 11,812.64 1.00) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \pi R_m S_c K_s) && \text{(Weight)} \\ &= 1,419.1 / (2 \pi 11.875 11,812.64 1.00) \\ &= 0.0016" \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |-0.0075 + 0 - (0.0016)| \\ &= \underline{0.0091"} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0 + (0.0016) - (-0.0075) \\ &= \underline{0.0091"} \end{aligned}$$

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Above Support Point

$$\begin{aligned} t_p &= 0" && \text{(Pressure)} \\ t_m &= M / (\pi R_m^2 S_c K_s) && \text{(bending)} \\ &= 47 / (\pi 11.875^2 5,750.24 1.00) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \pi R_m S_c K_s) && \text{(Weight)} \\ &= 1,419.1 / (2 \pi 11.875 5,750.24 1.00) \\ &= 0.0033" \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0 + 0 - (0.0033)| \\ &= \underline{0.0033"} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0 + (0.0033) - (0) \\ &= \underline{0.0033"} \end{aligned}$$

Operating, Hot & Corroded, Below Support Point

$$\begin{aligned} t_p &= P R / (2 S_c K_s + 0.40 |P|) && \text{(Pressure)} \\ &= 0 11.75 / (2 5,750.24 1.00 + 0.40 |0|) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_m &= M / (\pi R_m^2 S_c K_s) && \text{(bending)} \\ &= 0 / (\pi 11.875^2 5,750.24 1.00) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \pi R_m S_c K_s) && \text{(Weight)} \\ &= 1,419.1 / (2 \pi 11.875 5,750.24 1.00) \\ &= 0.0033" \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0 + 0 - (0.0033)| \\ &= \underline{0.0033"} \end{aligned}$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad \text{(total required, compressive)}$$

$$= 0 + (0.0033) - (0)$$

$$= \underline{0.0033''}$$

Maximum allowable working pressure, Longitudinal Stress

$$\begin{aligned} P &= 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w)) \\ &= 2*14,400*1.00*1.00*(0.2188 - 0 + (0.0013)) / (11.75 - 0.40*(0.2188 - 0 + (0.0013))) \\ &= 543.48 \text{ psi} \end{aligned}$$

Operating, Hot & New, Below Support Point

$$\begin{aligned} t_p &= P*R / (2*S_c*K_s + 0.40*|P|) && \text{(Pressure)} \\ &= 0*11.75 / (2*5,750.24*1.00 + 0.40*|0|) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_m &= M / (\pi*R_m^2*S_c*K_s) && \text{(bending)} \\ &= 0 / (\pi*11.875^2*5,750.24*1.00) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_w &= W / (2*\pi*R_m*S_c*K_s) && \text{(Weight)} \\ &= 1,419.1 / (2*\pi*11.875*5,750.24*1.00) \\ &= 0.0033'' \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0 + 0 - (0.0033)| \\ &= \underline{0.0033''} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0 + (0.0033) - (0) \\ &= \underline{0.0033''} \end{aligned}$$

Maximum allowable working pressure, Longitudinal Stress

$$\begin{aligned} P &= 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w)) \\ &= 2*14,400*1.00*1.00*(0.2188 - 0 + (0.0013)) / (11.75 - 0.40*(0.2188 - 0 + (0.0013))) \\ &= 543.48 \text{ psi} \end{aligned}$$

Hot Shut Down, Corroded, Below Support Point

$$\begin{aligned} t_p &= 0'' && \text{(Pressure)} \\ t_m &= M / (\pi*R_m^2*S_c*K_s) && \text{(bending)} \\ &= 0 / (\pi*11.875^2*5,750.24*1.00) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_w &= W / (2*\pi*R_m*S_c*K_s) && \text{(Weight)} \\ &= 1,419.1 / (2*\pi*11.875*5,750.24*1.00) \\ &= 0.0033'' \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0 + 0 - (0.0033)| \\ &= \underline{0.0033''} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0 + (0.0033) - (0) \end{aligned}$$

$$= 0.0033"$$

Hot Shut Down, New, Below Support Point

$$t_p = 0" \quad (\text{Pressure})$$

$$\begin{aligned} t_m &= M / (\pi R_m^2 S_c K_s) \quad (\text{bending}) \\ &= 0 / (\pi 11.875^2 5,750.24 1.00) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \pi R_m S_c K_s) \quad (\text{Weight}) \\ &= 1,419.1 / (2 \pi 11.875 5,750.24 1.00) \\ &= 0.0033" \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| \quad (\text{total, net compressive}) \\ &= |0 + 0 - (0.0033)| \\ &= 0.0033" \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive}) \\ &= 0 + (0.0033) - (0) \\ &= 0.0033" \end{aligned}$$

Empty, Corroded, Below Support Point

$$t_p = 0" \quad (\text{Pressure})$$

$$\begin{aligned} t_m &= M / (\pi R_m^2 S_c K_s) \quad (\text{bending}) \\ &= 0 / (\pi 11.875^2 11,812.64 1.00) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \pi R_m S_c K_s) \quad (\text{Weight}) \\ &= 1,419.1 / (2 \pi 11.875 11,812.64 1.00) \\ &= 0.0016" \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| \quad (\text{total, net compressive}) \\ &= |0 + 0 - (0.0016)| \\ &= 0.0016" \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive}) \\ &= 0 + (0.0016) - (0) \\ &= 0.0016" \end{aligned}$$

Empty, New, Below Support Point

$$t_p = 0" \quad (\text{Pressure})$$

$$\begin{aligned} t_m &= M / (\pi R_m^2 S_c K_s) \quad (\text{bending}) \\ &= 0 / (\pi 11.875^2 11,812.64 1.00) \\ &= 0" \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \pi R_m S_c K_s) \quad (\text{Weight}) \\ &= 1,419.1 / (2 \pi 11.875 11,812.64 1.00) \\ &= 0.0016" \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| \quad (\text{total, net compressive}) \\ &= |0 + 0 - (0.0016)| \\ &= 0.0016" \end{aligned}$$

$$\begin{aligned}
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0 + (0.0016) - (0) \\
 &= \underline{0.0016"}
 \end{aligned}$$

Vacuum, Below Support Point

$$\begin{aligned}
 t_p &= P \cdot R / (2 \cdot S_o \cdot K_s + 0.40 \cdot |P|) && \text{(Pressure)} \\
 &= -15 \cdot 11.75 / (2 \cdot 11,812.64 \cdot 1.00 + 0.40 \cdot |15|) \\
 &= -0.0075"
 \end{aligned}$$

$$\begin{aligned}
 t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\
 &= 0 / (\pi \cdot 11.875^2 \cdot 11,812.64 \cdot 1.00) \\
 &= 0"
 \end{aligned}$$

$$\begin{aligned}
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) && \text{(Weight)} \\
 &= 1,419.1 / (2 \cdot \pi \cdot 11.875 \cdot 11,812.64 \cdot 1.00) \\
 &= 0.0016"
 \end{aligned}$$

$$\begin{aligned}
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |-0.0075 + 0 - (0.0016)| \\
 &= \underline{0.0091"}
 \end{aligned}$$

$$\begin{aligned}
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0 + (0.0016) - (-0.0075) \\
 &= \underline{0.0091"}
 \end{aligned}$$

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Below Support Point

$$\begin{aligned}
 t_p &= 0" && \text{(Pressure)} \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\
 &= 0 / (\pi \cdot 11.875^2 \cdot 5,750.24 \cdot 1.00) \\
 &= 0"
 \end{aligned}$$

$$\begin{aligned}
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) && \text{(Weight)} \\
 &= 1,419.1 / (2 \cdot \pi \cdot 11.875 \cdot 5,750.24 \cdot 1.00) \\
 &= 0.0033"
 \end{aligned}$$

$$\begin{aligned}
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |0 + 0 - (0.0033)| \\
 &= \underline{0.0033"}
 \end{aligned}$$

$$\begin{aligned}
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0 + (0.0033) - (0) \\
 &= \underline{0.0033"}
 \end{aligned}$$

Bolted Cover #1

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Component: Bolted Cover
Material specification: SA-240 304L (II-D p. 82, ln. 38)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 0$ psi @ 932 °F
External design pressure: $P_e = 15$ psi @ 100 °F

Static liquid head:

$P_{th} = 0.85$ psi (SG=1.0000, $H_s=23.5$ ", Horizontal test head)

Corrosion allowance: Inner C = 0" Outer C = 0"

Design MDMT = -320 °F
Rated MDMT = -320 °F
No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Category A joints - Seamless No RT

Estimated weight: New = 570.5 lb corr = 570.5 lb

Head outside diameter = 32"

Cover thickness = 2.75"

Gasket groove depth = 0.093"

Design thickness, (at 70 °F) UG-34 (c)(2), gasket seating

$$\begin{aligned} t &= d \cdot \text{Sqr}(1.9 \cdot W \cdot h_g / (S \cdot E \cdot d^3)) + \text{Corrosion} \\ &= 25.8125 \cdot \text{Sqr}(1.9 \cdot 232,440 \cdot 1.8438 / (16,700 \cdot 1 \cdot 25.8125^3)) + 0 \\ &= 1.3744 \text{ in} \end{aligned}$$

Maximum allowable working pressure, (at 932 °F)

$$\begin{aligned} P &= (S \cdot E / C) \cdot ((t/d)^2 - (1.9 \cdot W \cdot h_g / (S \cdot E \cdot d^3))) - P_s \\ &= (10,600 \cdot 1 / 0.3) \cdot ((2.75 / 25.8125)^2 - (1.9 \cdot 155,618 \cdot 1.8438 / (10,600 \cdot 1 \cdot 25.8125^3))) - 0 \\ &= 295.38 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (At 70 °F)

$$\begin{aligned} P &= (S \cdot E / C) \cdot ((t/d)^2 - (1.9 \cdot W \cdot h_g / (S \cdot E \cdot d^3))) \\ &= (16,700 \cdot 1 / 0.3) \cdot ((2.75 / 25.8125)^2 - (1.9 \cdot 245,171.9 \cdot 1.8438 / (16,700 \cdot 1 \cdot 25.8125^3))) \\ &= 465.37 \text{ psi} \end{aligned}$$

Design thickness for external pressure, (at 100 °F) U-2(g)

$$\begin{aligned} t &= d \cdot \text{Sqr}(C \cdot P_a / (S \cdot E)) + \text{Corrosion} \\ &= 25.8125 \cdot \text{Sqr}(0.3 \cdot 15 / (16,700 \cdot 1)) + 0 \\ &= 0.4237 \text{ in} \end{aligned}$$

Maximum allowable external pressure, (At 100 °F) U-2(g)

$$P_a = (S \cdot E / C) \cdot (t/d)^2$$

$$\begin{aligned} &= (16,700 \cdot 1/0.3) \cdot (2.75/25.8125)^2 \\ &= 631.83 \text{ psi} \end{aligned}$$

Straight Flange on Bottom Ellipsoidal Head

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

Component: Straight Flange
Material specification: SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Pipe NPS and Schedule: 24" Sch 10S
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 0$ psi @ 932 °F
External design pressure: $P_e = 15$ psi @ 100 °F

Static liquid head:

$P_{th} = 0.85$ psi (SG = 1, $H_s = 23.5$ ", Horizontal test head)

Corrosion allowance Inner C = 0" Outer C = 0"

Design MDMT = -320 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - Full UW-11(a) Type 1
Circumferential joint - Full UW-11(a) Type 1

Estimated weight New = 8.1 lb corr = 8.1 lb
Capacity New = 2.82 US gal corr = 2.82 US gal

ID = 23.5"
Length L_c = 1.5"
 t = 0.25"

Maximum allowable working pressure, (at 932 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) - P_s \\ &= 14,400 \cdot 1.00 \cdot 0.2188 / (11.75 + 0.60 \cdot 0.2188) - 0 \\ &= 265.12 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

$$\begin{aligned} P &= S \cdot E \cdot t / (R + 0.60 \cdot t) \\ &= 20,000 \cdot 1.00 \cdot 0.2188 / (11.75 + 0.60 \cdot 0.2188) \\ &= 368.23 \text{ psi} \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$L / D_o = 66.1033 / 24 = 2.7543$
 $D_o / t = 24 / 0.1192 = 201.3703$
From table G: A = 0.000161
From table HA-1: B = 2,265 psi

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\ &= 4 \cdot 2265.4226 / (3 \cdot (24 / 0.1192)) \end{aligned}$$

$$= 15 \text{ psi}$$

Design thickness for external pressure $P_a = 15 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.1192 + 0 = 0.1192"$$

Maximum Allowable External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 66.1033 / 24 = 2.7543$$

$$D_o / t = 24 / 0.2188 = 109.7143$$

From table G: $A = 0.000405$

From table HA-1: $B = 5,689 \text{ psi}$

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\ &= 4 \cdot 5688.6738 / (3 \cdot (24 / 0.2188)) \\ &= 69.13 \text{ psi} \end{aligned}$$

Design thickness = 0.1192"

The governing condition is due to external pressure.

The cylinder thickness of 0.25" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
<u>Operating, Hot & Corroded</u>	0	14,400	<u>5,750</u>	932	0	Weight	<u>0</u>	<u>0</u>
<u>Operating, Hot & New</u>	0	14,400	<u>5,750</u>	932	0	Weight	<u>0</u>	<u>0</u>
<u>Hot Shut Down, Corroded</u>	0	14,400	<u>5,750</u>	932	0	Weight	<u>0</u>	<u>0</u>
<u>Hot Shut Down, New</u>	0	14,400	<u>5,750</u>	932	0	Weight	<u>0</u>	<u>0</u>
<u>Empty, Corroded</u>	0	20,000	<u>11,813</u>	70	0	Weight	<u>0</u>	<u>0</u>
<u>Empty, New</u>	0	20,000	<u>11,813</u>	70	0	Weight	<u>0</u>	<u>0</u>
<u>Vacuum</u>	-15	20,000	<u>11,813</u>	100	0	Weight	<u>0.0074</u>	<u>0.0074</u>
<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only</u>	0	14,400	<u>5,750</u>	932	0	Weight	<u>0</u>	<u>0</u>

Allowable Compressive Stress, Hot and Corroded- S_{cHC} (table HA-1)

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (12 / 0.2188) \\ &= 0.002279 \\ B &= 5,750 \text{ psi} \\ S &= 14,400 / 1.00 = 14,400 \text{ psi} \\ S_{cHC} &= \min(B, S) = \underline{5,750 \text{ psi}} \end{aligned}$$

Allowable Compressive Stress, Hot and New- S_{cHN}

$$\begin{aligned}
 S_{cHN} &= S_{cHC} \\
 &= \underline{5.750 \text{ psi}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and New- S_{cCN} , (table HA-1)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (12 / 0.2188) \\
 &= 0.002279 \\
 B &= 11,813 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cCN} &= \min(B, S) = \underline{11,813 \text{ psi}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$\begin{aligned}
 S_{cCC} &= S_{cCN} \\
 &= \underline{11,813 \text{ psi}}
 \end{aligned}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC} , (table HA-1)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (12 / 0.2188) \\
 &= 0.002279 \\
 B &= 11,813 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cVC} &= \min(B, S) = \underline{11,813 \text{ psi}}
 \end{aligned}$$

Operating, Hot & Corroded, Top Seam

$$\begin{aligned}
 t_p &= P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) && \text{(Pressure)} \\
 &= 0 \cdot 11.75 / (2 \cdot 14,400 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |0|) \\
 &= 0'' \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) && \text{(bending)} \\
 &= 0 / (\pi \cdot 11.875^2 \cdot 14,400 \cdot 1.00 \cdot 1.00) \\
 &= 0'' \\
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) && \text{(Weight)} \\
 &= -43.4 / (2 \cdot \pi \cdot 11.875 \cdot 14,400 \cdot 1.00 \cdot 1.00) \\
 &= 0'' \\
 t_t &= t_p + t_m - t_w && \text{(total required, tensile)} \\
 &= 0 + 0 - (0) \\
 &= \underline{0''} \\
 t_c &= |t_{mc} + t_{wc} - t_{pc}| && \text{(total, net tensile)} \\
 &= |0 + (0) - (0)| \\
 &= \underline{0''}
 \end{aligned}$$

Maximum allowable working pressure, Longitudinal Stress

$$\begin{aligned} P &= 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w)) \\ &= 2 * 14,400 * 1.00 * 1.00 * (0.2188 - 0 + (0)) / (11.75 - 0.40 * (0.2188 - 0 + (0))) \\ &= 540.09 \text{ psi} \end{aligned}$$

Operating. Hot & New. Top Seam

$$\begin{aligned} t_p &= P * R / (2 * S_t * K_s * E_c + 0.40 * |P|) && \text{(Pressure)} \\ &= 0 * 11.75 / (2 * 14,400 * 1.00 * 1.00 + 0.40 * |0|) \\ &= 0'' \\ t_m &= M / (\pi * R_m^2 * S_t * K_s * E_c) && \text{(bending)} \\ &= 0 / (\pi * 11.875^2 * 14,400 * 1.00 * 1.00) \\ &= 0'' \\ t_w &= W / (2 * \pi * R_m * S_t * K_s * E_c) && \text{(Weight)} \\ &= -43.4 / (2 * \pi * 11.875 * 14,400 * 1.00 * 1.00) \\ &= 0'' \\ t_t &= t_p + t_m - t_w && \text{(total required, tensile)} \\ &= 0 + 0 - (0) \\ &= \underline{0''} \\ t_c &= |t_{mc} + t_{wc} - t_{pc}| && \text{(total, net tensile)} \\ &= |0 + (0) - (0)| \\ &= \underline{0''} \end{aligned}$$

Maximum allowable working pressure, Longitudinal Stress

$$\begin{aligned} P &= 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w)) \\ &= 2 * 14,400 * 1.00 * 1.00 * (0.2188 - 0 + (0)) / (11.75 - 0.40 * (0.2188 - 0 + (0))) \\ &= 540.09 \text{ psi} \end{aligned}$$

Hot Shut Down. Corroded. Top Seam

$$\begin{aligned} t_p &= 0'' && \text{(Pressure)} \\ t_m &= M / (\pi * R_m^2 * S_t * K_s * E_c) && \text{(bending)} \\ &= 0 / (\pi * 11.875^2 * 14,400 * 1.00 * 1.00) \\ &= 0'' \\ t_w &= W / (2 * \pi * R_m * S_t * K_s * E_c) && \text{(Weight)} \\ &= -43.4 / (2 * \pi * 11.875 * 14,400 * 1.00 * 1.00) \\ &= 0'' \\ t_t &= t_p + t_m - t_w && \text{(total required, tensile)} \\ &= 0 + 0 - (0) \\ &= \underline{0''} \\ t_c &= |t_{mc} + t_{wc} - t_{pc}| && \text{(total, net tensile)} \end{aligned}$$

$$= |0 + (0) - (0)|$$

$$= \underline{0''}$$

Hot Shut Down, New, Top Seam

$$t_p = 0'' \quad (\text{Pressure})$$

$$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c) \quad (\text{bending})$$

$$= 0 / (\pi * 11.875^2 * 14,400 * 1.00 * 1.00)$$

$$= 0''$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_c) \quad (\text{Weight})$$

$$= -43.4 / (2 * \pi * 11.875 * 14,400 * 1.00 * 1.00)$$

$$= 0''$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 0 + 0 - (0)$$

$$= \underline{0''}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0 + (0) - (0)|$$

$$= \underline{0''}$$

Empty, Corroded, Top Seam

$$t_p = 0'' \quad (\text{Pressure})$$

$$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c) \quad (\text{bending})$$

$$= 0 / (\pi * 11.875^2 * 20,000 * 1.00 * 1.00)$$

$$= 0''$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_c) \quad (\text{Weight})$$

$$= -43.4 / (2 * \pi * 11.875 * 20,000 * 1.00 * 1.00)$$

$$= 0''$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 0 + 0 - (0)$$

$$= \underline{0''}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0 + (0) - (0)|$$

$$= \underline{0''}$$

Empty, New, Top Seam

$$t_p = 0'' \quad (\text{Pressure})$$

$$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c) \quad (\text{bending})$$

$$= 0 / (\pi * 11.875^2 * 20,000 * 1.00 * 1.00)$$

$$= 0''$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_c) \quad (\text{Weight})$$

$$= -43.4 / (2 * \pi * 11.875 * 20,000 * 1.00 * 1.00)$$

$$= 0''$$

$$\begin{aligned} t_t &= t_p + t_m - t_w && \text{(total required, tensile)} \\ &= 0 + 0 - (0) \\ &= \underline{0''} \end{aligned}$$

$$\begin{aligned} t_c &= |t_{mc} + t_{wc} - t_{pc}| && \text{(total, net tensile)} \\ &= |0 + (0) - (0)| \\ &= \underline{0''} \end{aligned}$$

Vacuum. Top Seam

$$\begin{aligned} t_p &= P \cdot R / (2 \cdot S_c \cdot K_s + 0.40 \cdot |P|) && \text{(Pressure)} \\ &= -15 \cdot 11.75 / (2 \cdot 11,812.64 \cdot 1.00 + 0.40 \cdot |15|) \\ &= -0.0075'' \end{aligned}$$

$$\begin{aligned} t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) && \text{(bending)} \\ &= 0 / (\pi \cdot 11.875^2 \cdot 11,812.64 \cdot 1.00) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) && \text{(Weight)} \\ &= -43.4 / (2 \cdot \pi \cdot 11.875 \cdot 11,812.64 \cdot 1.00) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |-0.0075 + 0 - (0)| \\ &= \underline{0.0074''} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0 + (0) - (-0.0075) \\ &= \underline{0.0074''} \end{aligned}$$

Hot Shut Down. Corroded. Weight & Eccentric Moments Only. Top Seam

$$\begin{aligned} t_p &= 0'' && \text{(Pressure)} \\ t_m &= M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) && \text{(bending)} \\ &= 0 / (\pi \cdot 11.875^2 \cdot 14,400 \cdot 1.00 \cdot 1.00) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) && \text{(Weight)} \\ &= -43.4 / (2 \cdot \pi \cdot 11.875 \cdot 14,400 \cdot 1.00 \cdot 1.00) \\ &= 0'' \end{aligned}$$

$$\begin{aligned} t_t &= t_p + t_m - t_w && \text{(total required, tensile)} \\ &= 0 + 0 - (0) \\ &= \underline{0''} \end{aligned}$$

$$\begin{aligned} t_c &= |t_{mc} + t_{wc} - t_{pc}| && \text{(total, net tensile)} \\ &= |0 + (0) - (0)| \\ &= \underline{0''} \end{aligned}$$

Bottom Ellipsoidal Head

ASME Section VIII, Division 1, 2007 Edition, A08 Addenda

Component: Ellipsoidal Head
Material Specification: SA-312 TP304 Wld & smls pipe (II-D p.90, ln. 15)
Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F

External design pressure: $P_e = 15 \text{ psi @ } 100 \text{ °F}$

Static liquid head:

$P_s = 0 \text{ psi (SG=1, } H_s=0" \text{ Operating head)}$
 $P_{th} = 0.8483 \text{ psi (SG=1, } H_s=23.5" \text{ Horizontal test head)}$

Corrosion allowance: Inner C = 0" Outer C = 0"

Design MDMT = -320 °F No impact test performed
Rated MDMT = N/A Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Full UW-11(a) Type 1
Head to shell seam - Full UW-11(a) Type 1

Estimated weight*: new = 43.4 lb corr = 43.4 lb
Capacity*: new = 10.2 US gal corr = 10.2 US gal
* includes straight flange

Inner diameter = 23.5"
Minimum head thickness = 0.1875"
Head ratio D/2h = 2 (new)
Head ratio D/2h = 2 (corroded)
Straight flange length L_{sf} = 1.5"
Nominal straight flange thickness t_{sf} = 0.25"

Results Summary

The governing condition is UG-16.

Minimum thickness per UG-16 = $0.0625" + 0" = 0.0625"$
Design thickness due to external pressure (t_e) = 0.0619"
Maximum allowable external pressure (MAEP) = 82.82 psi

Maximum allowable working pressure, (Corroded at 932 °F) UG-32(d)(1)

$$\begin{aligned} P &= 2SEt/(D + 0.2t) - P_s \\ &= 2 \cdot 14,400 \cdot 1 \cdot 0.1875 / (23.5 + 0.2 \cdot 0.1875) - 0 \\ &= 229.42 \text{ psi} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 229.42 psi.

Maximum allowable pressure, (New at 70 °F) UG-32(d)(1)

$$P = 2SEt/(D + 0.2t) - P_s$$

$$\begin{aligned}
 &= 2*20,000*1*0.1875/(23.5 + 0.2*0.1875) - 0 \\
 &= 318.64 \text{ psi}
 \end{aligned}$$

The maximum allowable pressure (MAP) is 318.64 psi.

Design thickness for external pressure, (Corroded at 100 °F) UG-33(d)

Equivalent outside spherical radius (R_o)

$$\begin{aligned}
 R_o &= K_o * D_o \\
 &= 0.8861 * 23.875 \\
 &= 21.1552 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 A &= 0.125 / (R_o/t) \\
 &= 0.125 / (21.1552/0.061844) \\
 &= 0.000365
 \end{aligned}$$

From Table HA-1: $B=5,131.1514$ psi

$$\begin{aligned}
 P_a &= B/(R_o/t) \\
 &= 5,131.151/(21.1552/0.061844) \\
 &= 15 \text{ psi}
 \end{aligned}$$

$$t = 0.0618" + \text{Corrosion} = 0.0618" + 0" = 0.0618"$$

Check the external pressure per UG-33(a)(1) UG-32(d)(1)

$$\begin{aligned}
 t &= 1.67 * P_a * D / (2 * S * E - 0.2 * 1.67 * P_a) + \text{Corrosion} \\
 &= 1.67 * 15 * 23.5 / (2 * 20,000 * 1 - 0.2 * 1.67 * 15) + 0 \\
 &= 0.0147"
 \end{aligned}$$

The head external pressure design thickness (t_a) is 0.0618".

Maximum Allowable External Pressure, (Corroded at 100 °F) UG-33(d)

Equivalent outside spherical radius (R_o)

$$\begin{aligned}
 R_o &= K_o * D_o \\
 &= 0.8861 * 23.875 \\
 &= 21.1552 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 A &= 0.125 / (R_o/t) \\
 &= 0.125 / (21.1552/0.1875) \\
 &= 0.001108
 \end{aligned}$$

From Table HA-1: $B=9,344.501$ psi

$$\begin{aligned}
 P_a &= B/(R_o/t) \\
 &= 9,344.501/(21.1552/0.1875) \\
 &= 82.8209 \text{ psi}
 \end{aligned}$$

Check the Maximum External Pressure, UG-33(a)(1) UG-32(d)(1)

$$\begin{aligned}
 P &= 2 * S * E * t / ((D + 0.2 * t) * 1.67) - P_{s2} \\
 &= 2 * 20,000 * 1 * 0.1875 / ((23.5 + 0.2 * 0.1875) * 1.67) - 0 \\
 &= 190.8 \text{ psi}
 \end{aligned}$$

The maximum allowable external pressure (MAEP) is 82.82 psi.

% Forming strain - UHA-44(a)(2)(b)

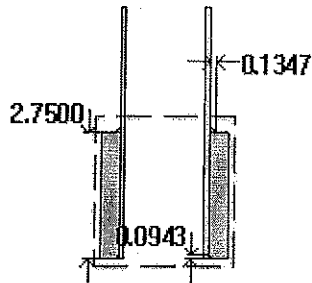
$$\begin{aligned} \text{EFE} &= (75 \cdot t / R_t) \cdot (1 - R_t / R_o) \\ &= (75 \cdot 0.25 / 4.12) \cdot (1 - 4.12 / \infty) \\ &= 4.551\% \end{aligned}$$

Copy of Copy of Nozzle #1 (N10)

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$$t_{w(\text{lower})} = 0.0943 \text{ in}$$

$$\text{Leg}_{41} = 0.1347 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-240 304L (II-D p. 82, ln. 38)
Nozzle longitudinal joint efficiency:	1
Nozzle orientation:	280°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	1.7305 in
Nozzle nominal wall thickness:	0.1348 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	9.5 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²) For $P_e = 481.85$ psi @ 100 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
2.0779	2.078	2.0106	0.0493	--	--	0.0181	0.1348	0.1348

UG-41 Weld Failure Path Analysis Summary (lb _f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
2.692.55	1.125.58	8.078.12	13.502.37	7.124.88

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0943	0.0943	weld size is adequate
Nozzle to shell groove (Lower)	0.0943	0.0943	weld size is adequate

Calculations for external pressure 481.85 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.7305, 0.8653 + (0.1348 - 0) + (2.75 - 0)) \\
 &= 3.75 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.1348 - 0) + 0) \\
 &= 0.3369 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 0.0616$ in

From UG-34 required thickness $t_r = 2.4015$ in

Area required per UG-39

Allowable stresses: $S_n = 16,700$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= 0.5*(1.7305*2.4015*1 + 2*0.1348*2.4015*1*(1 - 1)) \\ &= \underline{2.0779 \text{ in}^2} \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{2.0106 \text{ in}^2}$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 1.7305*(1*2.75 - 1*2.4015) - 2*0.1348*(1*2.75 - 1*2.4015)*(1 - 1) \\ &= 0.603 \text{ in}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(2.75 + 0.1348)*(1*2.75 - 1*2.4015) - 2*0.1348*(1*2.75 - 1*2.4015)*(1 - 1) \\ &= 2.0106 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0493 \text{ in}^2}$

$$\begin{aligned} &= 2*(t_n - t_m)*f_{r2}*L_{pr} \\ &= 2*(0.1348 - 0.0616)*1*3.25 \\ &= 0.4754 \text{ in}^2 \\ &= 5*(t_n - t_m)*f_{r2}*t_n \\ &= 5*(0.1348 - 0.0616)*1*0.1348 \\ &= 0.0493 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2*f_{r2} \\ &= 0.1347^2*1 \\ &= \underline{0.0181 \text{ in}^2} \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 2.0106 + 0.0493 + 0.0181 \\ &= \underline{2.078 \text{ in}^2} \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1348 \text{ in}$
 $t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.0943 \text{ in}}$
 $t_{1(\text{actual})} = 0.7*\text{Leg} = 0.7*0.1347 = 0.0943 \text{ in}$
The weld size t_1 is satisfactory.
 $t_{2(\text{actual})} = 0.0943 \text{ in}$
The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.1886 \geq 1.25 t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.0616 \text{ in}$$

$$\text{Wall thickness per UG-45(b)(2): } t_{r2} = 2.4015 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.0625 \text{ in}$$

$$\text{Standard wall pipe per UG-45(b)(4): } t_{r4} = 0.1348 \text{ in}$$

$$\text{The greater of } t_{r2} \text{ or } t_{r3}: t_{r5} = 2.4015 \text{ in}$$

$$\text{The lesser of } t_{r4} \text{ or } t_{r5}: t_{r6} = 0.1348 \text{ in}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.1348$ in

Available nozzle wall thickness new, $t_n = 0.1348$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\text{Groove weld in tension: } 0.74 * 16,700 = 12,358 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7 * 16,700 = 11,690 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49 * 16,700 = 8,183 \text{ psi}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) * \text{Nozzle OD} * \text{Leg} * S_f = (\pi/2) * 2 * 0.1348 * 8,183 = 3,462.82 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 1.8653 * 0.1348 * 11,690 = 4,615.3 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 2 * 0.0943 * 12,358 = 3,662.06 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * t_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (2.0779 - 2.0106 + 2 * 0.1348 * 1 * (1 * 2.75 - 1 * 2.4015)) * 16,700 \\ &= \underline{2,692.55 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.0493 + 0 + 0.0181 + 0) * 16,700 \\ &= \underline{1,125.58 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t_{r1} * f) * S_v \\ &= (0.0493 + 0 + 0.0181 + 0 + 2 * 0.1348 * 2.75 * 1) * 16,700 \\ &= \underline{13,502.37 \text{ lb}_f} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 1125.58 \text{ lb}_f$
Path 1-1 through (1) & (3) = $3,462.82 + 4,615.3 = 8,078.12 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 2692.55 \text{ lb}_f$
Path 2-2 through (1), (4) = $3,462.82 + 3,662.06 = 7,124.88 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

% Forming strain - UHA-44(a)(2)(a)

$$\begin{aligned} \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\ &= (50 \cdot 0.1348 / 0.9326) \cdot (1 - 0.9326 / \infty) \\ &= 7.2242\% \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 2 = 1.6250$$

$$D_o / t = 2 / 0.0616 = 32.4625$$

From table G: A = 0.004459

From table HA-3: B = 11,732 psi

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\ &= 4 \cdot 11731.5215 / (3 \cdot (2 / 0.0616)) \\ &= 481.85 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 481.85 \text{ psi}$

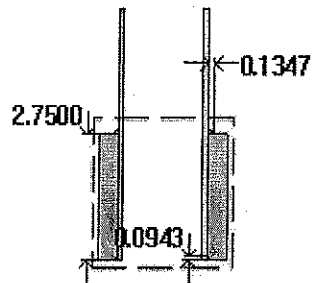
$$t_a = t + \text{Corrosion} = 0.0616 + 0 = 0.0616''$$

Copy of Copy of Nozzle #1 (N9)

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$$t_{w(\text{lower})} = 0.0943 \text{ in}$$

$$\text{Leg}_{41} = 0.1347 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-240 304L (II-D p. 82, In. 38)
Nozzle longitudinal joint efficiency:	1
Nozzle orientation:	200°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	1.7305 in
Nozzle nominal wall thickness:	0.1348 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	9.5 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 481.85$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
2.0779	2.078	2.0106	0.0493	--	--	0.0181	0.1348	0.1348

UG-41 Weld Failure Path Analysis Summary (lb _f)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
2,692.55	1,125.58	8,078.12	13,502.37	7,124.88

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0943	0.0943	weld size is adequate
Nozzle to shell groove (Lower)	0.0943	0.0943	weld size is adequate

Calculations for external pressure 481.85 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.7305, 0.8653 + (0.1348 - 0) + (2.75 - 0)) \\
 &= 3.75 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.1348 - 0) + 0) \\
 &= 0.3369 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0616$ in

From UG-34 required thickness $t_r = 2.4015$ in

Area required per UG-39

Allowable stresses: $S_n = 16,700$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5(1.7305 \cdot 2.4015 \cdot 1 + 2 \cdot 0.1348 \cdot 2.4015 \cdot 1 \cdot (1 - 1)) \\ &= \underline{2.0779 \text{ in}^2} \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{2.0106 \text{ in}^2}$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 1.7305(1 \cdot 2.75 - 1 \cdot 2.4015) - 2 \cdot 0.1348(1 \cdot 2.75 - 1 \cdot 2.4015)(1 - 1) \\ &= 0.603 \text{ in}^2 \\ &= 2 \cdot (t + t_n)(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 2 \cdot (2.75 + 0.1348)(1 \cdot 2.75 - 1 \cdot 2.4015) - 2 \cdot 0.1348(1 \cdot 2.75 - 1 \cdot 2.4015)(1 - 1) \\ &= 2.0106 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0493 \text{ in}^2}$

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.1348 - 0.0616) \cdot 1 \cdot 3.25 \\ &= 0.4754 \text{ in}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.1348 - 0.0616) \cdot 1 \cdot 0.1348 \\ &= 0.0493 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1347^2 \cdot 1 \\ &= \underline{0.0181 \text{ in}^2} \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 2.0106 + 0.0493 + 0.0181 \\ &= \underline{2.078 \text{ in}^2} \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1348 \text{ in}$
 $t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.0943 \text{ in}}$
 $t_{1(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1347 = 0.0943 \text{ in}$
The weld size t_1 is satisfactory.
 $t_{2(\text{actual})} = 0.0943 \text{ in}$
The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.1886 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.0616 \text{ in}$$

$$\text{Wall thickness per UG-45(b)(2): } t_{r2} = 2.4015 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.0625 \text{ in}$$

$$\text{Standard wall pipe per UG-45(b)(4): } t_{r4} = 0.1348 \text{ in}$$

$$\text{The greater of } t_{r2} \text{ or } t_{r3}: t_{r5} = 2.4015 \text{ in}$$

$$\text{The lesser of } t_{r4} \text{ or } t_{r5}: t_{r6} = 0.1348 \text{ in}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.1348}$ in

Available nozzle wall thickness new, $t_n = 0.1348$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\text{Groove weld in tension: } 0.74 \cdot 16,700 = 12,358 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7 \cdot 16,700 = 11,690 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49 \cdot 16,700 = 8,183 \text{ psi}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_f = (\pi/2) \cdot 2 \cdot 0.1347 \cdot 8,183 = 3,462.82 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = (\pi/2) \cdot 1.8653 \cdot 0.1348 \cdot 11,690 = 4,615.3 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi/2) \cdot 2 \cdot 0.0943 \cdot 12,358 = 3,662.06 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \cdot t_n \cdot t_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v \\ &= (2.0779 - 2.0106 + 2 \cdot 0.1348 \cdot 1 \cdot (1 \cdot 2.75 - 1 \cdot 2.4015)) \cdot 16,700 \\ &= \underline{2,692.55 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v \\ &= (0.0493 + 0 + 0.0181 + 0) \cdot 16,700 \\ &= \underline{1,125.58 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t_{r1}) \cdot S_v \\ &= (0.0493 + 0 + 0.0181 + 0 + 2 \cdot 0.1348 \cdot 2.75 \cdot 1) \cdot 16,700 \\ &= \underline{13,502.37 \text{ lb}_f} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 1125.58 \text{ lb}_f$
Path 1-1 through (1) & (3) = $3,462.82 + 4,615.3 = 8,078.12 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 2692.55 \text{ lb}_f$
Path 2-2 through (1), (4) = $3,462.82 + 3,662.06 = 7,124.88 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

% Forming strain - UHA-44(a)(2)(a)

$$\begin{aligned} \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\ &= (50 \cdot 0.1348 / 0.9326) \cdot (1 - 0.9326 / \infty) \\ &= 7.2242\% \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 2 = 1.6250$$

$$D_o / t = 2 / 0.0616 = 32.4625$$

From table G: A = 0.004459

From table HA-3: B = 11,732 psi

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\ &= 4 \cdot 11731.5215 / (3 \cdot (2 / 0.0616)) \\ &= 481.85 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 481.85 \text{ psi}$

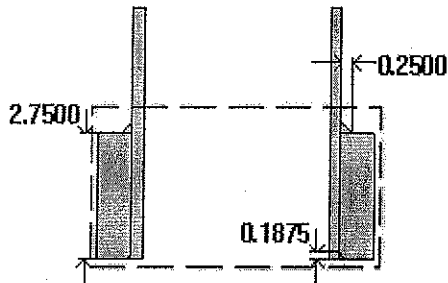
$$t_a = t + \text{Corrosion} = 0.0616 + 0 = 0.0616''$$

Copy of Copy of Nozzle #4 (N11)

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$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.25 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, In. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	4" Sch 40S (Std)
Nozzle orientation:	330°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	4.026 in
Nozzle nominal wall thickness:	0.237 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	7.56 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 363.62$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.1995	4.1996	3.9656	0.1715	--	--	0.0625	0.2074	0.2074

UG-41 Weld Failure Path Analysis Summary (lb _f)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
9,160.73	3,907.8	36,678.89	25,676.25	30,839.35

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.1659	0.175	weld size is adequate
Nozzle to shell groove (Lower)	0.1659	0.1875	weld size is adequate

Calculations for external pressure 363.62 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.026, 2.013 + (0.237 - 0) + (2.75 - 0)) \\
 &= 5 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.237 - 0) + 0) \\
 &= 0.5925 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0923$ in

From UG-34 required thickness $t_r = 2.0862$ in

Area required per UG-39

Allowable stresses: $S_n = 20,000$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5(4.026 \cdot 2.0862 \cdot 1 + 2 \cdot 0.237 \cdot 2.0862 \cdot 1 \cdot (1 - 1)) \\ &= \underline{4.1995} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{3.9656} \text{ in}^2$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 4.026(1 \cdot 2.75 - 1 \cdot 2.0862) - 2 \cdot 0.237(1 \cdot 2.75 - 1 \cdot 2.0862)(1 - 1) \\ &= 2.6725 \text{ in}^2 \\ &= 2 \cdot (t + t_n)(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 2 \cdot (2.75 + 0.237)(1 \cdot 2.75 - 1 \cdot 2.0862) - 2 \cdot 0.237(1 \cdot 2.75 - 1 \cdot 2.0862)(1 - 1) \\ &= \underline{3.9656} \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.1715} \text{ in}^2$

$$\begin{aligned} &= 2(t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2(0.237 - 0.0923) \cdot 1 \cdot 3.25 \\ &= 0.9405 \text{ in}^2 \\ &= 5(t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5(0.237 - 0.0923) \cdot 1 \cdot 0.237 \\ &= \underline{0.1715} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.25^2 \cdot 1 \\ &= \underline{0.0625} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 3.9656 + 0.1715 + 0.0625 \\ &= \underline{4.1996} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.237 \text{ in}$

$t_{1(\min)}$ or $t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.1659} \text{ in}$

$t_{1(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175 \text{ in}$

The weld size t_1 is satisfactory.

$t_{2(\text{actual})} = 0.1875 \text{ in}$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.3625 \geq 1.25 t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.0923 \text{ in}$$

$$\text{Wall thickness per UG-45(b)(2): } t_{r2} = 2.0862 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.0625 \text{ in}$$

$$\text{Standard wall pipe per UG-45(b)(4): } t_{r4} = 0.2074 \text{ in}$$

$$\text{The greater of } t_{r2} \text{ or } t_{r3}: t_{r5} = 2.0862 \text{ in}$$

$$\text{The lesser of } t_{r4} \text{ or } t_{r5}: t_{r6} = 0.2074 \text{ in}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.2074$ in

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\text{Groove weld in tension: } 0.74 \cdot 16,700 = 12,358 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7 \cdot 20,000 = 14,000 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49 \cdot 16,700 = 8,183 \text{ psi}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_f = (\pi/2) \cdot 4.5 \cdot 0.25 \cdot 8,183 = 14,460.55 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = (\pi/2) \cdot 4.263 \cdot 0.237 \cdot 14,000 = 22,218.34 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi/2) \cdot 4.5 \cdot 0.1875 \cdot 12,358 = 16,378.79 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v \\ &= (4.1995 - 3.9656 + 2 \cdot 0.237 \cdot 1 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862)) \cdot 16,700 \\ &= \underline{9,160.73 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0) \cdot 16,700 \\ &= \underline{3,907.8 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0 + 2 \cdot 0.237 \cdot 2.75 \cdot 1) \cdot 16,700 \\ &= \underline{25,676.25 \text{ lb}_f} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 3907.8 \text{ lb}_f$
Path 1-1 through (1) & (3) = $14,460.55 + 22,218.34 = 36,678.89 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 9160.73 \text{ lb}_f$
Path 2-2 through (1), (4) = $14,460.55 + 16,378.79 = 30,839.35 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 4.5 = 0.7222$$

$$D_o / t = 4.5 / 0.0923 = 48.7536$$

From table G: $A = 0.005779$

From table HA-1: $B = 13,296 \text{ psi}$

$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*13295.7129 / (3*(4.5 / 0.0923)) \\ &= 363.62 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 363.62 \text{ psi}$

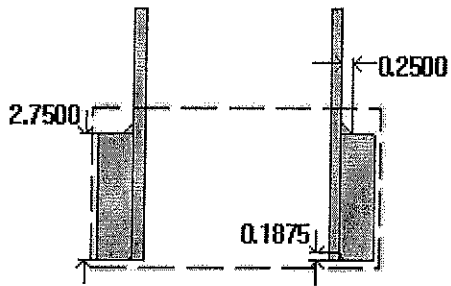
$$t_a = t + \text{Corrosion} = 0.0923 + 0 = 0.0923"$$

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$$t_{w(lower)} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.25 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	4" Sch 40S (Std)
Nozzle orientation:	240°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	4.026 in
Nozzle nominal wall thickness:	0.237 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	8 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 363.62$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.1995	4.1996	3.9656	0.1715	--	--	0.0625	0.2074	0.2074

UG-41 Weld Failure Path Analysis Summary (lb _f)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
9.160.73	3.907.8	36.678.89	25.676.25	30.839.35

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.1659	0.175	weld size is adequate
Nozzle to shell groove (Lower)	0.1659	0.1875	weld size is adequate

Calculations for external pressure 363.62 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.026, 2.013 + (0.237 - 0) + (2.75 - 0)) \\
 &= 5 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.237 - 0) + 0) \\
 &= 0.5925 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0923$ in

From UG-34 required thickness $t_r = 2.0862$ in

Area required per UG-39

Allowable stresses: $S_n = 20,000$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5(4.026 \cdot 2.0862 \cdot 1 + 2 \cdot 0.237 \cdot 2.0862 \cdot 1 \cdot (1 - 1)) \\ &= \underline{4.1995} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{3.9656} \text{ in}^2$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 4.026 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862) - 2 \cdot 0.237 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862) \cdot (1 - 1) \\ &= 2.6725 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (2.75 + 0.237) \cdot (1 \cdot 2.75 - 1 \cdot 2.0862) - 2 \cdot 0.237 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862) \cdot (1 - 1) \\ &= 3.9656 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.1715} \text{ in}^2$

$$\begin{aligned} &= 2 \cdot (t_n - t_m) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.237 - 0.0923) \cdot 1 \cdot 3.25 \\ &= 0.9405 \text{ in}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.237 - 0.0923) \cdot 1 \cdot 0.237 \\ &= 0.1715 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.25^2 \cdot 1 \\ &= \underline{0.0625} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 3.9656 + 0.1715 + 0.0625 \\ &= \underline{4.1996} \text{ in}^2 \end{aligned}$$

As Area $\geq A$ the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.237 \text{ in}$

$t_{1(\min)}$ or $t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.1659} \text{ in}$

$t_{1(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175 \text{ in}$

The weld size t_1 is satisfactory.

$t_{2(\text{actual})} = 0.1875 \text{ in}$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.3625 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.0923 \text{ in}$$

$$\text{Wall thickness per UG-45(b)(2): } t_{r2} = 2.0862 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.0625 \text{ in}$$

$$\text{Standard wall pipe per UG-45(b)(4): } t_{r4} = 0.2074 \text{ in}$$

$$\text{The greater of } t_{r2} \text{ or } t_{r3}: t_{r5} = 2.0862 \text{ in}$$

$$\text{The lesser of } t_{r4} \text{ or } t_{r5}: t_{r6} = 0.2074 \text{ in}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.2074$ in

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\text{Groove weld in tension: } 0.74 \cdot 16,700 = 12,358 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7 \cdot 20,000 = 14,000 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49 \cdot 16,700 = 8,183 \text{ psi}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_f = (\pi/2) \cdot 4.5 \cdot 0.25 \cdot 8,183 = 14,460.55 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = (\pi/2) \cdot 4.263 \cdot 0.237 \cdot 14,000 = 22,218.34 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi/2) \cdot 4.5 \cdot 0.1875 \cdot 12,358 = 16,378.79 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v \\ &= (4.1995 - 3.9656 + 2 \cdot 0.237 \cdot 1 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862)) \cdot 16,700 \\ &= \underline{9,160.73 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0) \cdot 16,700 \\ &= \underline{3,907.8 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0 + 2 \cdot 0.237 \cdot 2.75 \cdot 1) \cdot 16,700 \\ &= \underline{25,676.25 \text{ lb}_f} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 3907.8 \text{ lb}_f$
Path 1-1 through (1) & (3) = $14,460.55 + 22,218.34 = 36,678.89 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 9160.73 \text{ lb}_f$
Path 2-2 through (1), (4) = $14,460.55 + 16,378.79 = 30,839.35 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 4.5 = 0.7222$$

$$D_o / t = 4.5 / 0.0923 = 48.7536$$

From table G: $A = 0.005779$

From table HA-1: $B = 13,296 \text{ psi}$

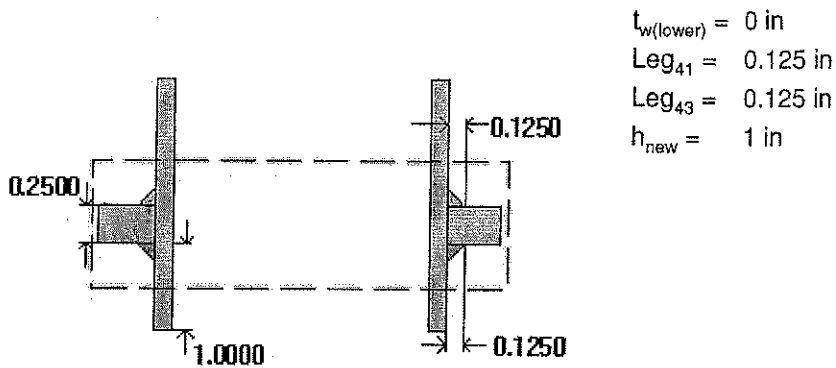
$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*13295.7129 / (3*(4.5 / 0.0923)) \\ &= 363.62 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 363.62 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0923 + 0 = 0.0923''$$

Copy of Nozzle #1 (N2)

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Note: round inside edges per UG-76(c)

Located on:	Vacuum Vessel Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-240 304L (II-D p. 82, ln. 38)
Nozzle longitudinal joint efficiency:	1
Nozzle orientation:	180°
Local vessel minimum thickness:	0.2188 in
Nozzle center line offset to datum line:	8 in
End of nozzle to shell center:	13 in
Nozzle inside diameter, new:	1.75 in
Nozzle nominal wall thickness:	0.125 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Internal projection, h_{new} :	1 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 56.26$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1806	0.1806	0.0293	0.0601	0.0652	--	0.026	0.0625	0.125

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0875	0.0875	weld size is adequate
Nozzle to inside shell fillet (Leg ₄₃)	0.0875	0.0875 (corroded)	weld size is adequate

Calculations for external pressure 56.26 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.75, 0.875 + (0.125 - 0) + (0.2188 - 0)) \\
 &= 1.75 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.2188 - 0), 2.5*(0.125 - 0) + 0) \\
 &= 0.3125 \text{ in}
 \end{aligned}$$

Inner Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(0.2188 - 0), 2.5*(0.125 - 0 - 0)) \\
 &= 0.3125 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_m = 0.0099$ in

From UG-37(d)(1) required thickness $t_r = 0.2017$ in

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 16,700$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 0.835$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 0.835$$

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5(1.75 \cdot 0.2017 \cdot 1 + 2 \cdot 0.125 \cdot 0.2017 \cdot 1 \cdot (1 - 0.835)) \\ &= \underline{0.1806} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0293} \text{ in}^2$$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 1.75(1 \cdot 0.2188 - 1 \cdot 0.2017) - 2 \cdot 0.125(1 \cdot 0.2188 - 1 \cdot 0.2017)(1 - 0.835) \\ &= 0.0293 \text{ in}^2 \\ &= 2 \cdot (t + t_n)(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 2 \cdot (0.2188 + 0.125)(1 \cdot 0.2188 - 1 \cdot 0.2017) - 2 \cdot 0.125(1 \cdot 0.2188 - 1 \cdot 0.2017)(1 - 0.835) \\ &= 0.0111 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.0601} \text{ in}^2$$

$$\begin{aligned} &= 5(t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5(0.125 - 0.0099) \cdot 0.835 \cdot 0.2188 \\ &= 0.1051 \text{ in}^2 \\ &= 5(t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5(0.125 - 0.0099) \cdot 0.835 \cdot 0.125 \\ &= 0.0601 \text{ in}^2 \end{aligned}$$

$$A_3 = \text{smaller of the following} = \underline{0.0652} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot t \cdot f_{r2} \\ &= 5 \cdot 0.2188 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.1142} \text{ in}^2 \\ &= 5 \cdot t \cdot f_{r2} \\ &= 5 \cdot 0.125 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.0652} \text{ in}^2 \\ &= 2 \cdot h \cdot t \cdot f_{r2} \\ &= 2 \cdot 1 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.2088} \text{ in}^2 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 * f_{r2} \\
 &= 0.125^2 * 0.835 \\
 &= \underline{0.013 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 * f_{r2} \\
 &= 0.125^2 * 0.835 \\
 &= \underline{0.013 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.0293 + 0.0601 + 0.0652 + 0.013 + 0.013 \\
 &= \underline{0.1806 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.125 \text{ in} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = \underline{0.0875 \text{ in}} \\
 t_{1(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 0.125 = 0.0875 \text{ in} \\
 \text{The weld size } t_1 &\text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 0.7 * \text{Leg} = 0.7 * 0.125 = 0.0875 \text{ in} \\
 \text{The weld size } t_2 &\text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 0.175 \geq 1.25 * t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} \quad t_{r1} &= 0.0099 \text{ in} \\
 \text{Wall thickness per UG-45(b)(2):} \quad t_{r2} &= 0.0331 \text{ in} \\
 \text{Wall thickness per UG-16(b):} \quad t_{r3} &= 0.0625 \text{ in} \\
 \text{Standard wall pipe per UG-45(b)(4):} \quad t_{r4} &= 0.1348 \text{ in} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: \quad t_{r5} &= 0.0625 \text{ in} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: \quad t_{r6} &= 0.0625 \text{ in}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.0625 \text{ in}}$

Available nozzle wall thickness new, $t_n = 0.125 \text{ in}$

The nozzle neck thickness is adequate.

% Forming strain - UHA-44(a)(2)(a)

$$\begin{aligned}
 \text{EFE} &= (50 * t / R_f) * (1 - R_f / R_o) \\
 &= (50 * 0.125 / 0.9375) * (1 - 0.9375 / \infty) \\
 &= 6.6667\%
 \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 1.0417 / 2 = 0.5209$$

$$D_o / t = 2 / 0.0099 = 201.8611$$

From table G: $A = 0.000924$

From table HA-3: $B = 8,518 \text{ psi}$

$$P_a = 4*B / (3*(D_o / t))$$

$$= 4*8518.4590 / (3*(2 / 0.0099))$$

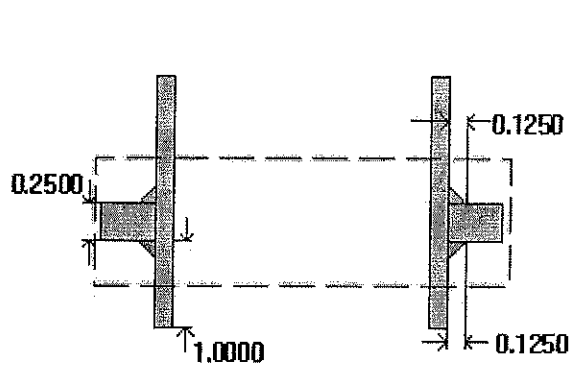
$$= 56.27 \text{ psi}$$

Design thickness for external pressure $P_a = 56.27 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0099 + 0 = 0.0099"$$

Copy of Nozzle #1 (N3)

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$$t_{w(lower)} = 0 \text{ in}$$

$$Leg_{41} = 0.125 \text{ in}$$

$$Leg_{43} = 0.125 \text{ in}$$

$$h_{new} = 1 \text{ in}$$

Note: round inside edges per UG-76(c)

Located on:	Vacuum Vessel Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-240 304L (II-D p. 82, ln. 38)
Nozzle longitudinal joint efficiency:	1
Nozzle orientation:	300°
Local vessel minimum thickness:	0.2188 in
Nozzle center line offset to datum line:	8 in
End of nozzle to shell center:	13 in
Nozzle inside diameter, new:	1.75 in
Nozzle nominal wall thickness:	0.125 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Internal projection, h_{new} :	1 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 56.26$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1806	0.1806	0.0293	0.0601	0.0652	--	0.026	0.0625	0.125

UG-41 Weld Failure Path Analysis Summary

Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0875	0.0875	weld size is adequate
Nozzle to inside shell fillet (Leg ₄₃)	0.0875	0.0875 (corroded)	weld size is adequate

Calculations for external pressure 56.26 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.75, 0.875 + (0.125 - 0) + (0.2188 - 0)) \\
 &= 1.75 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.2188 - 0), 2.5*(0.125 - 0) + 0) \\
 &= 0.3125 \text{ in}
 \end{aligned}$$

Inner Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(0.2188 - 0), 2.5*(0.125 - 0 - 0)) \\
 &= 0.3125 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0099$ in

From UG-37(d)(1) required thickness $t_r = 0.2017$ in

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 16,700$, $S_v = 20,000$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 0.835$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 0.835$

$$\begin{aligned} A &= 0.5(d t_r F + 2 t_n t_r F (1 - f_{r1})) \\ &= 0.5(1.75 \cdot 0.2017 \cdot 1 + 2 \cdot 0.125 \cdot 0.2017 \cdot 1 \cdot (1 - 0.835)) \\ &= \underline{0.1806} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.0293} \text{ in}^2$

$$\begin{aligned} &= d(E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ &= 1.75(1 \cdot 0.2188 - 1 \cdot 0.2017) - 2 \cdot 0.125(1 \cdot 0.2188 - 1 \cdot 0.2017)(1 - 0.835) \\ &= 0.0293 \text{ in}^2 \\ &= 2(t + t_n)(E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ &= 2(0.2188 + 0.125)(1 \cdot 0.2188 - 1 \cdot 0.2017) - 2 \cdot 0.125(1 \cdot 0.2188 - 1 \cdot 0.2017)(1 - 0.835) \\ &= 0.0111 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0601} \text{ in}^2$

$$\begin{aligned} &= 5(t_n - t_m) f_{r2} t \\ &= 5(0.125 - 0.0099) \cdot 0.835 \cdot 0.2188 \\ &= 0.1051 \text{ in}^2 \\ &= 5(t_n - t_m) f_{r2} t_n \\ &= 5(0.125 - 0.0099) \cdot 0.835 \cdot 0.125 \\ &= 0.0601 \text{ in}^2 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{0.0652} \text{ in}^2$

$$\begin{aligned} &= 5 t_i t_j f_{r2} \\ &= 5 \cdot 0.2188 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.1142} \text{ in}^2 \\ &= 5 t_i t_j f_{r2} \\ &= 5 \cdot 0.125 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.0652} \text{ in}^2 \\ &= 2 h t_i f_{r2} \\ &= 2 \cdot 1 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.2088} \text{ in}^2 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.125^2 \cdot 0.835 \\
 &= \underline{0.013 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.125^2 \cdot 0.835 \\
 &= \underline{0.013 \text{ in}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.0293 + 0.0601 + 0.0652 + 0.013 + 0.013 \\
 &= \underline{0.1806 \text{ in}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.125 \text{ in} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.0875 \text{ in}} \\
 t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875 \text{ in} \\
 \text{The weld size } t_1 &\text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875 \text{ in} \\
 \text{The weld size } t_2 &\text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 0.175 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.0099 \text{ in} \\
 \text{Wall thickness per UG-45(b)(2):} & \quad t_{r2} = 0.0331 \text{ in} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.0625 \text{ in} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.1348 \text{ in} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.0625 \text{ in} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.0625 \text{ in}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.0625 \text{ in}}$

Available nozzle wall thickness new, $t_n = 0.125 \text{ in}$

The nozzle neck thickness is adequate.

% Forming strain - UHA-44(a)(2)(a)

$$\begin{aligned}
 \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.125 / 0.9375) \cdot (1 - 0.9375 / \infty) \\
 &= 6.6667\%
 \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 1.0417 / 2 = 0.5209$$

$$D_o / t = 2 / 0.0099 = 201.8611$$

From table G: $A = 0.000924$

From table HA-3: $B = 8,518 \text{ psi}$

$$P_a = 4*B / (3*(D_o / t))$$

$$= 4*8518.4590 / (3*(2 / 0.0099))$$

$$= 56.27 \text{ psi}$$

Design thickness for external pressure $P_a = 56.27 \text{ psi}$

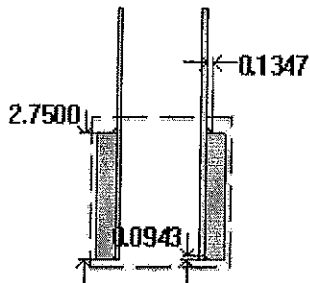
$$t_a = t + \text{Corrosion} = 0.0099 + 0 = 0.0099''$$

Copy of Nozzle #1 (N8)

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$$t_{w(\text{lower})} = 0.0943 \text{ in}$$

$$\text{Leg}_{41} = 0.1347 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-240 304L (II-D p. 82, ln. 38)
Nozzle longitudinal joint efficiency:	1
Nozzle orientation:	60°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	1.7305 in
Nozzle nominal wall thickness:	0.1348 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	9.5 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²) For $P_e = 481.85$ psi @ 100 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
2.0779	2.078	2.0106	0.0493	--	--	0.0181	0.1348	0.1348

UG-41 Weld Failure Path Analysis Summary (lb _f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
2.692.55	1.125.58	8.078.12	13.502.37	7.124.88

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0943	0.0943	weld size is adequate
Nozzle to shell groove (Lower)	0.0943	0.0943	weld size is adequate

Calculations for external pressure 481.85 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.7305, 0.8653 + (0.1348 - 0) + (2.75 - 0)) \\
 &= 3.75 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.1348 - 0) + 0) \\
 &= 0.3369 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0616$ in

From UG-34 required thickness $t_r = 2.4015$ in

Area required per UG-39

Allowable stresses: $S_n = 16,700$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= 0.5*(1.7305*2.4015*1 + 2*0.1348*2.4015*1*(1 - 1)) \\ &= \underline{2.0779} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{2.0106} \text{ in}^2$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 1.7305*(1*2.75 - 1*2.4015) - 2*0.1348*(1*2.75 - 1*2.4015)*(1 - 1) \\ &= 0.603 \text{ in}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(2.75 + 0.1348)*(1*2.75 - 1*2.4015) - 2*0.1348*(1*2.75 - 1*2.4015)*(1 - 1) \\ &= 2.0106 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0493} \text{ in}^2$

$$\begin{aligned} &= 2*(t_n - t_{rn})*f_{r2}*L_{pr} \\ &= 2*(0.1348 - 0.0616)*1*3.25 \\ &= 0.4754 \text{ in}^2 \\ &= 5*(t_n - t_{rn})*f_{r2}*t_n \\ &= 5*(0.1348 - 0.0616)*1*0.1348 \\ &= 0.0493 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2*f_{r2} \\ &= 0.1347^2*1 \\ &= \underline{0.0181} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 2.0106 + 0.0493 + 0.0181 \\ &= \underline{2.078} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.1348 \text{ in}$

$t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.0943} \text{ in}$

$t_{1(\text{actual})} = 0.7*\text{Leg} = 0.7*0.1347 = 0.0943 \text{ in}$

The weld size t_1 is satisfactory.

$t_{2(\text{actual})} = 0.0943 \text{ in}$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.1886 \geq 1.25 * t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.0616 \text{ in}$$

$$\text{Wall thickness per UG-45(b)(2): } t_{r2} = 2.4015 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.0625 \text{ in}$$

$$\text{Standard wall pipe per UG-45(b)(4): } t_{r4} = 0.1348 \text{ in}$$

$$\text{The greater of } t_{r2} \text{ or } t_{r3}: t_{r5} = 2.4015 \text{ in}$$

$$\text{The lesser of } t_{r4} \text{ or } t_{r5}: t_{r6} = 0.1348 \text{ in}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.1348}$ in

Available nozzle wall thickness new, $t_n = 0.1348$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\text{Groove weld in tension: } 0.74 * 16,700 = 12,358 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7 * 16,700 = 11,690 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49 * 16,700 = 8,183 \text{ psi}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) * \text{Nozzle OD} * \text{Leg} * S_f = (\pi/2) * 2 * 0.1347 * 8,183 = 3,462.82 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 1.8653 * 0.1348 * 11,690 = 4,615.3 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 2 * 0.0943 * 12,358 = 3,662.06 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * t_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (2.0779 - 2.0106 + 2 * 0.1348 * 1 * (1 * 2.75 - 1 * 2.4015)) * 16,700 \\ &= \underline{2,692.55} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.0493 + 0 + 0.0181 + 0) * 16,700 \\ &= \underline{1,125.58} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t_{r1}) * S_v \\ &= (0.0493 + 0 + 0.0181 + 0 + 2 * 0.1348 * 2.75 * 1) * 16,700 \\ &= \underline{13,502.37} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1,1} = 1125.58 \text{ lb}_f$
Path 1-1 through (1) & (3) = $3,462.82 + 4,615.3 = 8,078.12 \text{ lb}_f$
Path 1-1 is stronger than $W_{1,1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2,2} = 2692.55 \text{ lb}_f$
Path 2-2 through (1), (4) = $3,462.82 + 3,662.06 = 7,124.88 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

% Forming strain - UHA-44(a)(2)(a)

$$\begin{aligned} \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\ &= (50 \cdot 0.1348 / 0.9326) \cdot (1 - 0.9326 / \infty) \\ &= 7.2242\% \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 2 = 1.6250$$

$$D_o / t = 2 / 0.0616 = 32.4625$$

From table G: $A = 0.004459$

From table HA-3: $B = 11,732 \text{ psi}$

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o / t)) \\ &= 4 \cdot 11731.5215 / (3 \cdot (2 / 0.0616)) \\ &= 481.85 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 481.85 \text{ psi}$

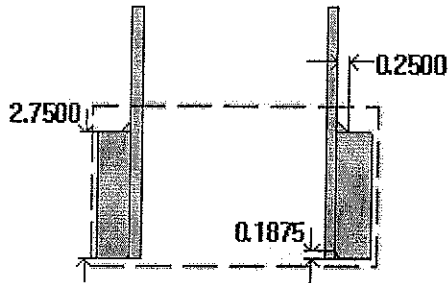
$$t_a = t + \text{Corrosion} = 0.0616 + 0 = 0.0616"$$

Copy of Nozzle #4 (N5)

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$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$Leg_{41} = 0.25 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	4" Sch 40S (Std)
Nozzle orientation:	30°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	4.026 in
Nozzle nominal wall thickness:	0.237 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, L _{pr} :	3.25 in
Distance to head center, R:	7.56 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 363.62$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.1995	4.1996	3.9656	0.1715	--	--	0.0625	0.2074	0.2074

UG-41 Weld Failure Path Analysis Summary (lb _f)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
9,160.73	3,907.8	36,678.89	25,676.25	30,839.35

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.1659	0.175	weld size is adequate
Nozzle to shell groove (Lower)	0.1659	0.1875	weld size is adequate

Calculations for external pressure 363.62 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.026, 2.013 + (0.237 - 0) + (2.75 - 0)) \\
 &= 5 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.237 - 0) + 0) \\
 &= 0.5925 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0923$ in

From UG-34 required thickness $t_r = 2.0862$ in

Area required per UG-39

Allowable stresses: $S_n = 20,000$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= 0.5*(4.026*2.0862*1 + 2*0.237*2.0862*1*(1 - 1)) \\ &= \underline{4.1995} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{3.9656} \text{ in}^2$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 4.026*(1*2.75 - 1*2.0862) - 2*0.237*(1*2.75 - 1*2.0862)*(1 - 1) \\ &= 2.6725 \text{ in}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(2.75 + 0.237)*(1*2.75 - 1*2.0862) - 2*0.237*(1*2.75 - 1*2.0862)*(1 - 1) \\ &= 3.9656 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.1715} \text{ in}^2$

$$\begin{aligned} &= 2*(t_n - t_m)*f_{r2}*L_{pr} \\ &= 2*(0.237 - 0.0923)*1*3.25 \\ &= 0.9405 \text{ in}^2 \\ &= 5*(t_n - t_m)*f_{r2}*t_n \\ &= 5*(0.237 - 0.0923)*1*0.237 \\ &= 0.1715 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2*f_{r2} \\ &= 0.25^2*1 \\ &= \underline{0.0625} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 3.9656 + 0.1715 + 0.0625 \\ &= \underline{4.1996} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.237 \text{ in}$

$t_{1(\min)}$ or $t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.1659} \text{ in}$

$t_{1(\text{actual})} = 0.7*\text{Leg} = 0.7*0.25 = 0.175 \text{ in}$

The weld size t_1 is satisfactory.

$t_{2(\text{actual})} = 0.1875 \text{ in}$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.3625 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	$t_{r1} = 0.0923$ in
Wall thickness per UG-45(b)(2):	$t_{r2} = 2.0862$ in
Wall thickness per UG-16(b):	$t_{r3} = 0.0625$ in
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 0.2074$ in
The greater of t_{r2} or t_{r3} :	$t_{r5} = 2.0862$ in
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 0.2074$ in

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.2074}$ in

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension: $0.74 \cdot 16,700 = 12,358$ psi

Nozzle wall in shear: $0.7 \cdot 20,000 = 14,000$ psi

Inner fillet weld in shear: $0.49 \cdot 16,700 = 8,183$ psi

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = (\pi/2) \cdot 4.5 \cdot 0.25 \cdot 8,183 = 14,460.55 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = (\pi/2) \cdot 4.263 \cdot 0.237 \cdot 14,000 = 22,218.34 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi/2) \cdot 4.5 \cdot 0.1875 \cdot 12,358 = 16,378.79 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v \\ &= (4.1995 - 3.9656 + 2 \cdot 0.237 \cdot 1 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862)) \cdot 16,700 \\ &= \underline{9,160.73} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0) \cdot 16,700 \\ &= \underline{3,907.8} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0 + 2 \cdot 0.237 \cdot 2.75 \cdot 1) \cdot 16,700 \\ &= \underline{25,676.25} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 3907.8 \text{ lb}_f$
Path 1-1 through (1) & (3) = $14,460.55 + 22,218.34 = 36,678.89 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 9160.73 \text{ lb}_f$
Path 2-2 through (1), (4) = $14,460.55 + 16,378.79 = 30,839.35 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 4.5 = 0.7222$$

$$D_o / t = 4.5 / 0.0923 = 48.7536$$

From table G: $A = 0.005779$

From table HA-1: $B = 13,296 \text{ psi}$

$$\begin{aligned} P_a &= 4B / (3(D_o / t)) \\ &= 4 * 13295.7129 / (3 * (4.5 / 0.0923)) \\ &= 363.62 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 363.62 \text{ psi}$

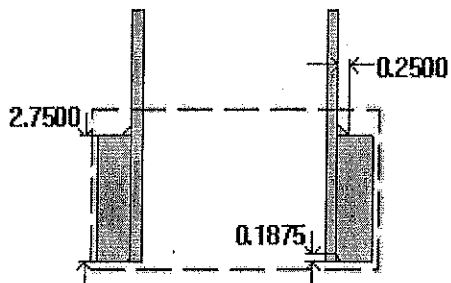
$$t_a = t + \text{Corrosion} = 0.0923 + 0 = 0.0923''$$

Copy of Nozzle #4 (N6)

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$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.25 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	4" Sch 40S (Std)
Nozzle orientation:	90°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	4.026 in
Nozzle nominal wall thickness:	0.237 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	7.5 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²) For $P_e = 363.62$ psi @ 100 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.1995	4.1996	3.9656	0.1715	--	--	0.0625	0.2074	0.2074

UG-41 Weld Failure Path Analysis Summary (lb _f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
9.160.73	3.907.8	36.678.89	25,676.25	30.839.35

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.1659	0.175	weld size is adequate
Nozzle to shell groove (Lower)	0.1659	0.1875	weld size is adequate

Calculations for external pressure 363.62 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.026, 2.013 + (0.237 - 0) + (2.75 - 0)) \\
 &= 5 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.237 - 0) + 0) \\
 &= 0.5925 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0923$ in

From UG-34 required thickness $t_r = 2.0862$ in

Area required per UG-39

Allowable stresses: $S_n = 20,000$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= 0.5*(4.026*2.0862*1 + 2*0.237*2.0862*1*(1 - 1)) \\ &= \underline{4.1995} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{3.9656} \text{ in}^2$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 4.026*(1*2.75 - 1*2.0862) - 2*0.237*(1*2.75 - 1*2.0862)*(1 - 1) \\ &= 2.6725 \text{ in}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(2.75 + 0.237)*(1*2.75 - 1*2.0862) - 2*0.237*(1*2.75 - 1*2.0862)*(1 - 1) \\ &= 3.9656 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.1715} \text{ in}^2$

$$\begin{aligned} &= 2*(t_n - t_m)*f_{r2}*L_{pr} \\ &= 2*(0.237 - 0.0923)*1*3.25 \\ &= 0.9405 \text{ in}^2 \\ &= 5*(t_n - t_m)*f_{r2}*t_n \\ &= 5*(0.237 - 0.0923)*1*0.237 \\ &= 0.1715 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2*f_{r2} \\ &= 0.25^2*1 \\ &= \underline{0.0625} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 3.9656 + 0.1715 + 0.0625 \\ &= \underline{4.1996} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.237 \text{ in}$

$t_{1(\min)}$ or $t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.1659} \text{ in}$

$t_{1(\text{actual})} = 0.7*\text{Leg} = 0.7*0.25 = 0.175 \text{ in}$

The weld size t_1 is satisfactory.

$t_{2(\text{actual})} = 0.1875 \text{ in}$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.3625 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	$t_{r1} = 0.0923$ in
Wall thickness per UG-45(b)(2):	$t_{r2} = 2.0862$ in
Wall thickness per UG-16(b):	$t_{r3} = 0.0625$ in
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 0.2074$ in
The greater of t_{r2} or t_{r3} :	$t_{r5} = 2.0862$ in
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 0.2074$ in

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.2074}$ in

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension:	$0.74 \cdot 16,700 = 12,358$ psi
Nozzle wall in shear:	$0.7 \cdot 20,000 = 14,000$ psi
Inner fillet weld in shear:	$0.49 \cdot 16,700 = 8,183$ psi

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_f = (\pi/2) \cdot 4.5 \cdot 0.25 \cdot 8,183 = 14,460.55 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = (\pi/2) \cdot 4.263 \cdot 0.237 \cdot 14,000 = 22,218.34 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = (\pi/2) \cdot 4.5 \cdot 0.1875 \cdot 12,358 = 16,378.79 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v \\ &= (4.1995 - 3.9656 + 2 \cdot 0.237 \cdot 1 \cdot (1 \cdot 2.75 - 1 \cdot 2.0862)) \cdot 16,700 \\ &= \underline{9,160.73} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0) \cdot 16,700 \\ &= \underline{3,907.8} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v \\ &= (0.1715 + 0 + 0.0625 + 0 + 2 \cdot 0.237 \cdot 2.75 \cdot 1) \cdot 16,700 \\ &= \underline{25,676.25} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 3907.8 \text{ lb}_f$
Path 1-1 through (1) & (3) = $14,460.55 + 22,218.34 = 36,678.89 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 9160.73 \text{ lb}_f$
Path 2-2 through (1), (4) = $14,460.55 + 16,378.79 = 30,839.35 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 4.5 = 0.7222$$

$$D_o / t = 4.5 / 0.0923 = 48.7536$$

From table G: A = 0.005779

From table HA-1: B = 13,296 psi

$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*13295.7129 / (3*(4.5 / 0.0923)) \\ &= 363.62 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 363.62 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0923 + 0 = 0.0923''$$

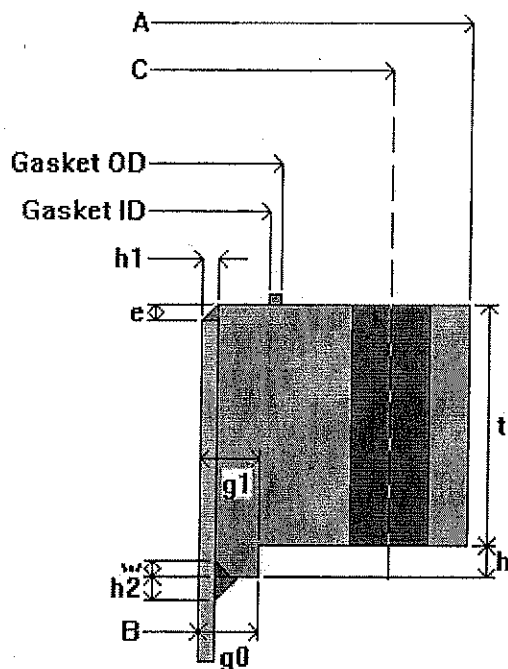
Flange #1

ASME VIII-1, 2007 Edition, A08 Addenda, Appendix 2 Flange Calculations

Flange is attached to:	Vacuum Vessel Shell (Top)	
Flange type:	Slip on integral	
Flange material specification:	SA-240 304L (II-D p. 82, ln. 38)	
Bolt material specification:	SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 348, ln. 33)	
Bolt Description:	1.25 in Series 8 Thread	
Internal design pressure, P_i :	0 psi @ 932 °F	
Required flange thickness: t_r :	3.0036 in	
Maximum allowable working pressure, MAWP:	235.89 psi @ 932 °F	
Maximum allowable pressure, MAP:	542.88 psi @ 70 °F	
External design pressure, P_e :	15 psi @ 100 °F	
Maximum allowable external pressure, MAEP:	2,046.96 psi @ 100 °F	
Corrosion allowance:	Bore = 0 in	Flange = 0 in
Bolt corrosion (root), C_{bolt} :	0 in	
Design MDMT:	-320 °F	No impact test performed
Rated MDMT:	-320 °F	Flange material is not normalized
		Material is not produced to fine grain practice
		PWHT is not performed
		corroded = 413.3 lb
Estimated weight:	New = 413.3 lb	

Flange dimensions, new

flange OD	A = 32 in
bolt circle	C = 29.5 in
gasket OD	= 26 in
gasket ID	= 25.625 in
flange ID	B = 23.5 in
thickness	t = 3.75 in
bolting	= 20- 1.25 in dia
hub thickness	g_1 = 0.935 in
hub thickness	g_0 = 0.935 in
hub length	h = 0.5 in
upper fillet weld	h1 = 0.25 in
lower fillet weld	h2 = 0.375 in
groove weld	w = 0.25 in
length	e = 0.25 in



gasket factor $m = 1$
 seating stress $y = 200 \text{ psi}$
 Gasket thickness $T = 0.175 \text{ in}$
 gasket description Elastomers without
 fabric 75A or higher
 Shore Durometer

Note: this flange is an optional type calculated as integral.

ASME Interpretation VIII-1-83-115 has been applied.

The following values are used in the calculations: g_0 = shell/nozzle wall thickness, h = actual length of flange hub plus fillet weld leg attaching hub to shell/nozzle

Flange calculations for External Pressure + Weight Only per VIII-1, Appendix 2-11

Longitudinal bending moment on flange

$$\begin{aligned}P_m &= 16 \cdot M_b / (\pi \cdot G^3) \\&= 16 \cdot 46.8 / (\pi \cdot 25.8125^3) \\&= 0.0139 \text{ psi}\end{aligned}$$

Axial load on flange

$$\begin{aligned}P_r &= 4 \cdot F / (\pi \cdot G^2) \\&= 4 \cdot 673.12 / (\pi \cdot 25.8125^2) \\&= 1.2863 \text{ psi}\end{aligned}$$

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$$\begin{aligned}&= P + P_s + P_m + P_r \\&= 15 + 0 + 0.0139 + 1.2863 \\&= 16.3002 \text{ psi}\end{aligned}$$

The static head of liquid has not been included in the total design load because the vessel is supported below the flange.

Gasket details from facing sketch 6, Column I

Ring gasket width $w = 0.1875$ in

$$b_0 = w/8 = 0.0234 \text{ in}$$

Effective gasket seating width, $b = b_0 = 0.0234$ in

$$G = (\text{gasket OD} + \text{gasket ID}) / 2 = (26 + 25.625) / 2 = 25.8125 \text{ in}$$

$$h_G = (C - G) / 2 = (29.5 - 25.8125) / 2 = 1.8438 \text{ in}$$

$$h_D = R + g_1 / 2 = 2.065 + 0.935 / 2 = 2.5325 \text{ in}$$

$$h_T = (R + g_1 + h_G) / 2 = (2.065 + 0.935 + 1.8438) / 2 = 2.4219 \text{ in}$$

$$\begin{aligned}H_p &= 2 \cdot b \cdot 3.14 \cdot G \cdot m \cdot P \\&= 2 \cdot 0.0234 \cdot 3.14 \cdot 25.8125 \cdot 1 \cdot 15 \\&= 56.99 \text{ lb}_f\end{aligned}$$

$$\begin{aligned}H &= 0.785 \cdot G^2 \cdot P \\&= 0.785 \cdot 25.8125^2 \cdot 16.3002 \\&= 8,525.56 \text{ lb}_f\end{aligned}$$

$$\begin{aligned}H_D &= 0.785 \cdot B^2 \cdot P \\&= 0.785 \cdot 23.5^2 \cdot 15 \\&= 6,502.74 \text{ lb}_f\end{aligned}$$

$$\begin{aligned}H_T &= H - H_D \\&= 8,525.56 - 6,502.74 \\&= 2,022.81 \text{ lb}_f\end{aligned}$$

$$\begin{aligned}W_{m1} &= H + H_p \\&= 8,525.56 + 56.99 \\&= 8,582.55 \text{ lb}_f\end{aligned}$$

$$\begin{aligned}
 W_{m2} &= 3.14 * b * G * y \\
 &= 3.14 * 0.0234 * 25.8125 * 200 \\
 &= 379.93 \text{ lb}_f
 \end{aligned}$$

Required bolt area, $A_m = \text{greater of } A_{m1}, A_{m2} = 0.01519711 \text{ in}^2$

$$A_{m1} = 0.785 * G^2 * (P_m - P_r) / S_b = 0 / 25,000 = 0 \text{ in}^2$$

$$A_{m2} = W_{m2} / S_a = 379.93 / 25,000 = 0.0152 \text{ in}^2$$

Total area for 20- 1.25 in dia bolts, corroded, $A_b = 18.58 \text{ in}^2$

$$\begin{aligned}
 W &= (A_{m2} + A_b) * S_a / 2 \\
 &= (0.0152 + 18.58) * 25,000 / 2 \\
 &= 232,439.97 \text{ lb}_f
 \end{aligned}$$

$$\begin{aligned}
 M_o &= H_D * (h_D - h_G) + H_T * (h_T - h_G) \\
 &= 6,502.74 * (2.5325 - 1.8438) + 2,022.81 * (2.4219 - 1.8438) \\
 &= 5,648.2 \text{ lb-in}
 \end{aligned}$$

$$M_g = W * h_G = 232,440 * 1.8438 = 428,561.2 \text{ lb-in}$$

Hub and Flange Factors

$$h_o = (B * g_o)^{1/2} = (23.5 * 0.2188)^{1/2} = 2.2673 \text{ in}$$

From FIG. 2-7.1, where $K = A/B = 32/23.5 = 1.3617$

$$T = 1.7709 \quad Z = 3.3413 \quad Y = 6.4482 \quad U = 7.0859$$

$$h/h_o = 0.3859 \quad g_1/g_o = 4.1314$$

$$F = 0.8541 \quad V = 0.1712 \quad e = F/h_o = 0.3767$$

$$\begin{aligned}
 d &= (U/V) * h_o * g_o^2 = (7.085897 / 0.1712) * 2.2673 * 0.2188^2 \\
 &= 4.4916 \text{ in}^3
 \end{aligned}$$

Stresses at operating conditions - VIII-1, Appendix 2-7

$$f = 7.3586$$

$$\begin{aligned}
 L &= (t * e + 1) / T + t^3 / d \\
 &= (3.75 * 0.3767 + 1) / 1.77085 + 3.75^3 / 4.4916 \\
 &= 13.10312
 \end{aligned}$$

$$\begin{aligned}
 S_H &= f * M_o / (L * g_1^2 * B) \\
 &= 7.3586 * 5,648.2 / (13.10312 * 0.9038^2 * 23.5) \\
 &= 165 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 S_R &= (1.33 * t * e + 1) * M_o / (L * t^2 * B) \\
 &= (1.33 * 3.75 * 0.3767 + 1) * 5,648.2 / (13.10312 * 3.75^2 * 23.5) \\
 &= 4 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 S_T &= Y * M_o / (t^2 * B) - Z * S_R \\
 &= 6.4482 * 5,648.2 / (3.75^2 * 23.5) - 3.3413 * 4 \\
 &= 98 \text{ psi}
 \end{aligned}$$

Allowable stress $S_{to} = 16,700 \text{ psi}$

Allowable stress $S_{no} = 20,000 \text{ psi}$

S_T does not exceed S_{fo}

S_H does not exceed $\text{Min}[1.5*S_{fo}, 1.5*S_{no}] = 25,050 \text{ psi}$

S_R does not exceed S_{fo}

$0.5(S_H + S_R) = 85 \text{ psi}$ does not exceed S_{fo}

$0.5(S_H + S_T) = 131 \text{ psi}$ does not exceed S_{fo}

Stresses at gasket seating - VIII-1, Appendix 2-7

$$S_H = f*M_g/(L*g_1^2*B)$$

$$= 7.3586*428,561.2/(13.10312*0.9038^2*23.5)$$

$$= 12,539 \text{ psi}$$

$$S_R = (1.33*t*e + 1)*M_g/(L*t^2*B)$$

$$= (1.33*3.75*0.3767 + 1)*428,561.2/(13.10312*3.75^2*23.5)$$

$$= 285 \text{ psi}$$

$$S_T = Y*M_g/(t^2*B) - Z*S_R$$

$$= 6.4482*428,561.2/(3.75^2*23.5) - 3.3413*285$$

$$= 7,410 \text{ psi}$$

Allowable stress $S_{fa} = 16,700 \text{ psi}$

Allowable stress $S_{na} = 20,000 \text{ psi}$

S_T does not exceed S_{fa}

S_H does not exceed $\text{Min}[1.5*S_{fa}, 1.5*S_{na}] = 25,050 \text{ psi}$

S_R does not exceed S_{fa}

$0.5(S_H + S_R) = 6,412 \text{ psi}$ does not exceed S_{fa}

$0.5(S_H + S_T) = 9,975 \text{ psi}$ does not exceed S_{fa}

Flange rigidity per VIII-1, Appendix 2-14

$$J = 52.14*V*M_g/(L*E*g_0^2*K_I*h_0)$$

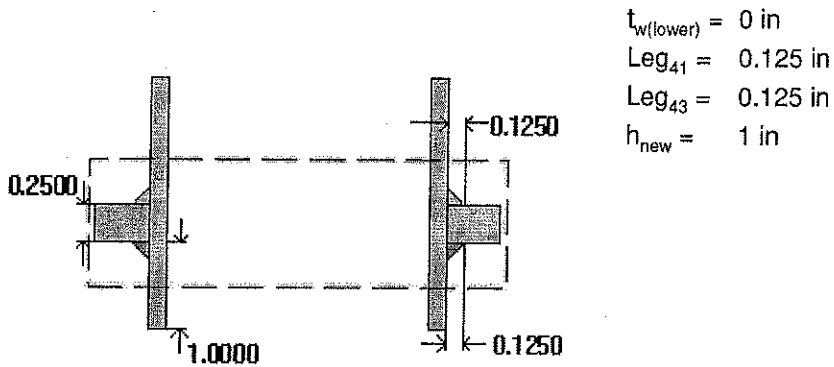
$$= 52.14*0.1712*428,561.2/(13.1031*28,300,000*0.2188^2*0.3*2.2673)$$

$$= 0.3168806$$

The flange rigidity index J does not exceed 1; satisfactory.

Nozzle #1 (N1)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda



Note: round inside edges per UG-76(c)

Located on:	Vacuum Vessel Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-240 304L (II-D p. 82, In. 38)
Nozzle longitudinal joint efficiency:	1
Nozzle orientation:	60°
Local vessel minimum thickness:	0.2188 in
Nozzle center line offset to datum line:	8 in
End of nozzle to shell center:	13 in
Nozzle inside diameter, new:	1.75 in
Nozzle nominal wall thickness:	0.125 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, L _{pr} :	1 in
Internal projection, h _{new} :	1 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in ²) For $P_e = 56.26$ psi @ 100 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
0.1806	0.1806	0.0293	0.0601	0.0652	--	0.026	0.0625	0.125

UG-41 Weld Failure Path Analysis Summary

Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.0875	0.0875	weld size is adequate
Nozzle to inside shell fillet (Leg ₄₃)	0.0875	0.0875 (corroded)	weld size is adequate

Calculations for external pressure 56.26 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.75, 0.875 + (0.125 - 0) + (0.2188 - 0)) \\
 &= 1.75 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.2188 - 0), 2.5*(0.125 - 0) + 0) \\
 &= 0.3125 \text{ in}
 \end{aligned}$$

Inner Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(0.2188 - 0), 2.5*(0.125 - 0 - 0)) \\
 &= 0.3125 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_{rn} = 0.0099$ in

From UG-37(d)(1) required thickness $t_r = 0.2017$ in

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 16,700$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 0.835$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 0.835$$

$$\begin{aligned} A &= 0.5(d t_r F + 2 t_n t_r F (1 - f_{r1})) \\ &= 0.5(1.75 \cdot 0.2017 \cdot 1 + 2 \cdot 0.125 \cdot 0.2017 \cdot 1 \cdot (1 - 0.835)) \\ &= \underline{0.1806} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.0293} \text{ in}^2$

$$\begin{aligned} &= d(E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ &= 1.75(1 \cdot 0.2188 - 1 \cdot 0.2017) - 2 \cdot 0.125(1 \cdot 0.2188 - 1 \cdot 0.2017) \cdot (1 - 0.835) \\ &= 0.0293 \text{ in}^2 \\ &= 2(t + t_n)(E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ &= 2(0.2188 + 0.125)(1 \cdot 0.2188 - 1 \cdot 0.2017) - 2 \cdot 0.125(1 \cdot 0.2188 - 1 \cdot 0.2017) \cdot (1 - 0.835) \\ &= 0.0111 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.0601} \text{ in}^2$

$$\begin{aligned} &= 5(t_n - t_m) f_{r2} t \\ &= 5(0.125 - 0.0099) \cdot 0.835 \cdot 0.2188 \\ &= 0.1051 \text{ in}^2 \\ &= 5(t_n - t_m) f_{r2} t_n \\ &= 5(0.125 - 0.0099) \cdot 0.835 \cdot 0.125 \\ &= 0.0601 \text{ in}^2 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{0.0652} \text{ in}^2$

$$\begin{aligned} &= 5 t_l f_{r2} \\ &= 5 \cdot 0.2188 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.1142} \text{ in}^2 \\ &= 5 t_l t_l f_{r2} \\ &= 5 \cdot 0.125 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.0652} \text{ in}^2 \\ &= 2 h t_l f_{r2} \\ &= 2 \cdot 1 \cdot 0.125 \cdot 0.835 \\ &= \underline{0.2088} \text{ in}^2 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.125^2 \cdot 0.835 \\
 &= \underline{0.013} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.125^2 \cdot 0.835 \\
 &= \underline{0.013} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.0293 + 0.0601 + 0.0652 + 0.013 + 0.013 \\
 &= \underline{0.1806} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.125 \text{ in} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.0875} \text{ in} \\
 t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875 \text{ in} \\
 \text{The weld size } t_1 &\text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875 \text{ in} \\
 \text{The weld size } t_2 &\text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 0.175 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.0099 \text{ in} \\
 \text{Wall thickness per UG-45(b)(2):} & \quad t_{r2} = 0.0331 \text{ in} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.0625 \text{ in} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.1348 \text{ in} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.0625 \text{ in} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.0625 \text{ in}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{0.0625}$ in

Available nozzle wall thickness new, $t_n = 0.125$ in

The nozzle neck thickness is adequate.

% Forming strain - UHA-44(a)(2)(a)

$$\begin{aligned}
 \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.125 / 0.9375) \cdot (1 - 0.9375 / \infty) \\
 &= 6.6667\%
 \end{aligned}$$

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 1.0417 / 2 = 0.5209$$

$$D_o / t = 2 / 0.0099 = 201.8611$$

From table G: $A = 0.000924$

From table HA-3: $B = 8,518 \text{ psi}$

$$\begin{aligned} P_a &= 4 * B / (3 * (D_o / t)) \\ &= 4 * 8518.4590 / (3 * (2 / 0.0099)) \\ &= 56.27 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 56.27 \text{ psi}$

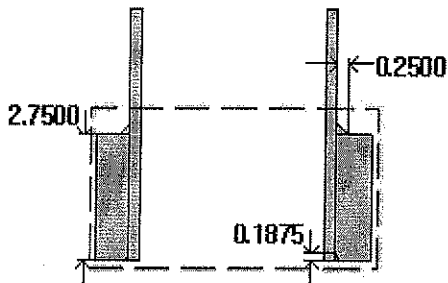
$$t_a = t + \text{Corrosion} = 0.0099 + 0 = 0.0099"$$

Nozzle #4 (N4)

ASME Section VIII Division 1, 2007 Edition, A08 Addenda

$$t_{w(lower)} = 0.1875 \text{ in}$$

$$Leg_{41} = 0.25 \text{ in}$$



Note: round inside edges per UG-76(c)

Located on:	Bolted Cover #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 90, ln. 15)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	4" Sch 40S (Std)
Nozzle orientation:	0°
Local vessel minimum thickness:	2.75 in
Nozzle inside diameter, new:	4.026 in
Nozzle nominal wall thickness:	0.237 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.25 in
Distance to head center, R:	0 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in ²)							UG-45 Nozzle Wall Thickness Summary (in)	
For $P_e = 363.62$ psi @ 100 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.1995	4.1996	3.9656	0.1715	--	--	0.0625	0.2074	0.2074

UG-41 Weld Failure Path Analysis Summary (lb _f)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
9.160.73	3.907.8	36.678.89	25.676.25	30.839.35

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.1659	0.175	weld size is adequate
Nozzle to shell groove (Lower)	0.1659	0.1875	weld size is adequate

Calculations for external pressure 363.62 psi @ 100 °F

Parallel Limits of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.026, 2.013 + (0.237 - 0) + (2.75 - 0)) \\
 &= 5 \text{ in}
 \end{aligned}$$

Outer Normal Limits of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_g) \\
 &= \text{MIN}(2.5*(2.75 - 0), 2.5*(0.237 - 0) + 0) \\
 &= 0.5925 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-28 $t_n = 0.0923$ in

From UG-34 required thickness $t_r = 2.0862$ in

Area required per UG-39

Allowable stresses: $S_n = 20,000$, $S_v = 16,700$ psi

$f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned} A &= 0.5(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})) \\ &= 0.5(4.026*2.0862*1 + 2*0.237*2.0862*1*(1 - 1)) \\ &= \underline{4.1995 \text{ in}^2} \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{3.9656 \text{ in}^2}$

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 4.026*(1*2.75 - 1*2.0862) - 2*0.237*(1*2.75 - 1*2.0862)*(1 - 1) \\ &= 2.6725 \text{ in}^2 \\ &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(2.75 + 0.237)*(1*2.75 - 1*2.0862) - 2*0.237*(1*2.75 - 1*2.0862)*(1 - 1) \\ &= 3.9656 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{0.1715 \text{ in}^2}$

$$\begin{aligned} &= 2*(t_n - t_{rn})*f_{r2}*L_{pr} \\ &= 2*(0.237 - 0.0923)*1*3.25 \\ &= 0.9405 \text{ in}^2 \\ &= 5*(t_n - t_{rn})*f_{r2}*t_n \\ &= 5*(0.237 - 0.0923)*1*0.237 \\ &= 0.1715 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2*f_{r2} \\ &= 0.25^2*1 \\ &= \underline{0.0625 \text{ in}^2} \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 3.9656 + 0.1715 + 0.0625 \\ &= \underline{4.1996 \text{ in}^2} \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.237 \text{ in}$
 $t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.1659 \text{ in}}$
 $t_{1(\text{actual})} = 0.7*\text{Leg} = 0.7*0.25 = 0.175 \text{ in}$
The weld size t_1 is satisfactory.
 $t_{2(\text{actual})} = 0.1875 \text{ in}$
The weld size t_2 is satisfactory.

$$t_1 + t_2 = 0.3625 \geq 1.25 t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.0923 \text{ in}$$

$$\text{Wall thickness per UG-45(b)(2): } t_{r2} = 2.0862 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.0625 \text{ in}$$

$$\text{Standard wall pipe per UG-45(b)(4): } t_{r4} = 0.2074 \text{ in}$$

$$\text{The greater of } t_{r2} \text{ or } t_{r3}: t_{r5} = 2.0862 \text{ in}$$

$$\text{The lesser of } t_{r4} \text{ or } t_{r5}: t_{r6} = 0.2074 \text{ in}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.2074$ in

$$\text{Available nozzle wall thickness new, } t_n = 0.875 * 0.237 = 0.2074 \text{ in}$$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\text{Groove weld in tension: } 0.74 * 16,700 = 12,358 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7 * 20,000 = 14,000 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49 * 16,700 = 8,183 \text{ psi}$$

Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi/2) * \text{Nozzle OD} * \text{Leg} * S_f = (\pi/2) * 4.5 * 0.25 * 8,183 = 14,460.55 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 4.263 * 0.237 * 14,000 = 22,218.34 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 4.5 * 0.1875 * 12,358 = 16,378.79 \text{ lb}_f$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * t_{r1} * (E_1 * t - F * t_1)) * S_v \\ &= (4.1995 - 3.9656 + 2 * 0.237 * 1 * (1 * 2.75 - 1 * 2.0862)) * 16,700 \\ &= \underline{9,160.73 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.1715 + 0 + 0.0625 + 0) * 16,700 \\ &= \underline{3,907.8 \text{ lb}_f} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t_{f1}) * S_v \\ &= (0.1715 + 0 + 0.0625 + 0 + 2 * 0.237 * 2.75 * 1) * 16,700 \\ &= \underline{25,676.25 \text{ lb}_f} \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1} = 3907.8 \text{ lb}_f$
Path 1-1 through (1) & (3) = $14,460.55 + 22,218.34 = 36,678.89 \text{ lb}_f$
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 9160.73 \text{ lb}_f$
Path 2-2 through (1), (4) = $14,460.55 + 16,378.79 = 30,839.35 \text{ lb}_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

External Pressure, (Corroded & at 100 °F) UG-28(c)

$$L / D_o = 3.25 / 4.5 = 0.7222$$

$$D_o / t = 4.5 / 0.0923 = 48.7536$$

From table G: $A = 0.005779$

From table HA-1: $B = 13,296 \text{ psi}$

$$\begin{aligned} P_a &= 4*B / (3*(D_o / t)) \\ &= 4*13295.7129 / (3*(4.5 / 0.0923)) \\ &= 363.62 \text{ psi} \end{aligned}$$

Design thickness for external pressure $P_a = 363.62 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0923 + 0 = 0.0923"$$

Legs #1

Leg material:			
Leg description:			3 inch sch 40 pipe
Number of legs:	N =	3	
Overall length:		13.5	in
Base to girth seam length:		11.5	in
Bolt circle:		26	in
Anchor bolt size:		0.375	inch series 8 threaded
Anchor bolt material:			
Anchor bolts/leg:		1	
Anchor bolt allowable stress:	S _b =	20,000	psi
Anchor bolt corrosion allowance:		0	in
Anchor bolt hole clearance:		0.375	in
Base plate width:		4	in
Base plate length:		4	in
Base plate thickness:		0.375	in (<u>0.022</u> in required)
Base plate allowable stress:		24,000	psi
Foundation allowable bearing stress:		1,658	psi
Effective length coefficient:	K =	1.2	
Coefficient:	C _m =	0.85	
Leg yield stress:	F _y =	36,000	psi
Leg elastic modulus:	E =	29,000,000	psi
Leg to shell fillet weld:		0.25	in (<u>0.0098</u> in required)
Legs braced:		No	

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Loading	Force attack angle °	Leg position °	Axial end load lb _f	Shear resisted lb _f	Axial f _a psi	Bending f _{bx} psi	Bending f _{by} psi	Ratio H ₁₋₁	Ratio H ₁₋₂
Governing Condition Weight operating corroded Moment = 3.9 lb-ft	0	0	479.0	0.0	215	486	0	0.0275	0.0304
		120	<u>484.2</u>	0.0	<u>217</u>	<u>491</u>	<u>0</u>	<u>0.0278</u>	<u>0.0307</u>
		240	484.2	0.0	217	491	0	0.0278	0.0307

Loading	Force attack angle °	Leg position °	Axial end load lb _f	Shear resisted lb _f	Axial f _a psi	Bending f _{bx} psi	Bending f _{by} psi	Ratio H ₁₋₁	Ratio H ₁₋₂
Weight empty corroded Moment = 3.9 lb-ft	0	0	479.0	0.0	215	486	0	0.0275	0.0304
		120	484.2	0.0	217	491	0	0.0278	0.0307
		240	484.2	0.0	217	491	0	0.0278	0.0307

Loading	Force attack angle °	Leg position °	Axial end load lb _f	Shear resisted lb _f	Axial f _a psi	Bending f _{bx} psi	Bending f _{by} psi	Ratio H ₁₋₁	Ratio H ₁₋₂
Weight vacuum corroded Moment = 3.9 lb-ft	0	0	479.0	0.0	215	486	0	0.0275	0.0304
		120	484.2	0.0	217	491	0	0.0278	0.0307
		240	484.2	0.0	217	491	0	0.0278	0.0307

Leg Calculations (AISC manual ninth edition)

Axial end load, P₁ (Based on vessel total bending moment acting at leg attachment elevation)

$$\begin{aligned}
 P_1 &= W/N + 48 \cdot M_1 / (N \cdot D) \\
 &= 1,444.91 / 3 + 48 \cdot 3.9 / (3 \cdot 24) \\
 &= \underline{484.24} \text{ lb}_f
 \end{aligned}$$

Allowable axial compressive stress, F_a (AISC chapter E)

$$\begin{aligned}
 C_c &= \text{Sqr}(2 \cdot \pi^2 \cdot E / F_y) \\
 &= \text{Sqr}(2 \cdot \pi^2 \cdot 29,000,000 / 36,000) \\
 &= 126.0993
 \end{aligned}$$

$$K \cdot l / r = 1.2 \cdot 10 / 1.1637 = 10.3117$$

$$\begin{aligned}
 F_a &= 1 \cdot (1 - (Kl/r)^2 / (2 \cdot C_c^2)) \cdot F_y / (5/3 + 3 \cdot (Kl/r) / (8 \cdot C_c) - (Kl/r)^3 / (8 \cdot C_c^3)) \\
 &= 1 \cdot (1 - (10.3117)^2 / (2 \cdot 126.0993^2)) \cdot 36,000 / (5/3 + 3 \cdot (10.3117) / (8 \cdot 126.0993) - (10.3117)^3 / (8 \cdot 126.0993^3)) \\
 &= 21,140 \text{ psi}
 \end{aligned}$$

Allowable axial compression and bending (AISC chapter H)

$$\begin{aligned}
 F'_{ex} &= 1 \cdot 12 \cdot \pi^2 \cdot E / (23 \cdot (Kl/r)^2) \\
 &= 1 \cdot 12 \cdot \pi^2 \cdot 29,000,000 / (23 \cdot (10.3117)^2) \\
 &= 1,404,400 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 F'_{ey} &= 1 \cdot 12 \cdot \pi^2 \cdot E / (23 \cdot (Kl/r)^2) \\
 &= 1 \cdot 12 \cdot \pi^2 \cdot 29,000,000 / (23 \cdot (10.3117)^2) \\
 &= 1,404,400 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 F_b &= 1 \cdot 0.66 \cdot F_y \\
 &= 1 \cdot 0.66 \cdot 36,000 \\
 &= 23,760 \text{ psi}
 \end{aligned}$$

Compressive axial stress

$$\begin{aligned}
 f_a &= P_1 / A \\
 &= 484.24 / 2.23 \\
 &= \underline{217} \text{ psi}
 \end{aligned}$$

Bending stresses

$$\begin{aligned}
 f_{bx} &= F \cdot \cos(\alpha) \cdot L / (I_x / C_x) + P_1 \cdot E_{cc} / (I_x / C_x) \\
 &= 0 \cdot \cos(120) \cdot 10 / (3.02 / 1.75) + 484.24 \cdot 1.75 / (3.02 / 1.75) \\
 &= \underline{491} \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 f_{by} &= F \cdot \sin(\alpha) \cdot L / (I_y / C_y) \\
 &= 0 \cdot \sin(120) \cdot 10 / (3.02 / 1.75) \\
 &= \underline{0} \text{ psi}
 \end{aligned}$$

AISC equation H_{1-1}

$$\begin{aligned}
 H_{1-1} &= f_a / F_a + C_{mx} \cdot f_{bx} / ((1 - f_a / F'_{ex}) \cdot F_{bx}) + C_{my} \cdot f_{by} / ((1 - f_a / F'_{ey}) \cdot F_{by}) \\
 &= 217 / 21,140 + 0.85 \cdot 491 / ((1 - 217 / 1,404,400) \cdot 23,760) + 0.85 \cdot 0 / ((1 - 217 / 1,404,400) \cdot 23,760) \\
 &= \underline{0.0278}
 \end{aligned}$$

AISC equation H_{1-2}

$$\begin{aligned}
 H_{1-2} &= f_a / (0.6 \cdot 1 \cdot F_y) + f_{bx} / F_{bx} + f_{by} / F_{by} \\
 &= 217 / (0.6 \cdot 1 \cdot 36,000) + 491 / 23,760 + 0 / 23,760 \\
 &= \underline{0.0307}
 \end{aligned}$$

3, 3 inch sch 40 pipe legs are adequate.

Anchor bolts - Weight operating corroded condition governs

Tensile loading per leg (1 bolt per leg)

$$\begin{aligned} R &= 48 * M / (N * BC) - W / N \\ &= 48 * 3.9 / (3 * 26) - 1,444.91 / 3 \\ &= -479.23 \text{ lb}_f \end{aligned}$$

There is no net uplift (R is negative).

0.375 inch series 8 threaded bolts are satisfactory.

Check the leg to vessel fillet weld, Bednar 10.3, Weight operating corroded governs

Note: continuous welding is assumed for all support leg fillet welds.

$$\begin{aligned} Z_w &= (2 * b * d + d^2) / 3 \\ &= (2 * 1.8028 * 3.5 + 3.5^2) / 3 \\ &= 8.2898 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} J_w &= (b + 2 * d)^3 / 12 - d^2 * (b + d)^2 / (b + 2 * d) \\ &= (1.8028 + 2 * 3.5)^3 / 12 - 3.5^2 * (1.8028 + 3.5)^2 / (1.8028 + 2 * 3.5) \\ &= 17.7119 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} E &= d^2 / (b + 2 * d) \\ &= 3.5^2 / (1.8028 + 2 * 3.5) \\ &= 1.391607 \text{ in} \end{aligned}$$

$$\text{Governing weld load } f_x = \cos(120) * 0 = 0 \text{ lb}_f$$

$$\text{Governing weld load } f_y = \sin(120) * 0 = 0 \text{ lb}_f$$

$$\begin{aligned} f_1 &= P_1 / L_{\text{weld}} \\ &= 484.24 / 8.8028 \\ &= 55.01 \text{ lb}_f / \text{in} \quad (V_L \text{ direct shear}) \end{aligned}$$

$$\begin{aligned} f_2 &= f_y * L_{\text{leg}} * 0.5 * b / J_w \\ &= 0 * 10 * 0.5 * 1.8028 / 17.7119 \\ &= 0 \text{ lb}_f / \text{in} \quad (V_L \text{ torsion shear}) \end{aligned}$$

$$\begin{aligned} f_3 &= f_y / L_{\text{weld}} \\ &= 0 / 8.8028 \\ &= 0 \text{ lb}_f / \text{in} \quad (V_c \text{ direct shear}) \end{aligned}$$

$$\begin{aligned} f_4 &= f_y * L_{\text{leg}} * E / J_w \\ &= 0 * 10 * 1.3916 / 17.7119 \\ &= 0 \text{ lb}_f / \text{in} \quad (V_c \text{ torsion shear}) \end{aligned}$$

$$\begin{aligned} f_5 &= f_x * L_{\text{leg}} / Z_w \\ &= 0 * 10 / 8.2898 \\ &= 0 \text{ lb}_f / \text{in} \quad (M_L \text{ bending}) \end{aligned}$$

$$\begin{aligned} f_6 &= f_x / L_{\text{weld}} \\ &= 0 / 8.8028 \\ &= 0 \text{ lb}_f / \text{in} \quad (\text{Direct outward radial shear}) \end{aligned}$$

$$\begin{aligned}
 f &= \text{Sqr}((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2) \\
 &= \text{Sqr}((55.01 + 0)^2 + (0 + 0)^2 + (0 + 0)^2) \\
 &= 55.01 \text{ lb}_f/\text{in} \text{ (Resultant shear load)}
 \end{aligned}$$

Required leg to vessel fillet weld leg size (welded both sides + top)

$$\begin{aligned}
 t_w &= f / (0.707 * 0.55 * S_a) \\
 &= 55.01 / (0.707 * 0.55 * 14,400) \\
 &= \underline{0.0098} \text{ in}
 \end{aligned}$$

The 0.25 in leg to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$$\begin{aligned}
 f_p &= P / (B * N) \\
 &= 484.04 / (4 * 4) \\
 &= 30 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 t_b &= (N - (d - t_L)) / 2 * \text{Sqr}(3 * f_p / S_b) \\
 &= (4 - (3.5 - 0.216)) / 2 * \text{Sqr}(3 * 30 / 24,000) \\
 &= \underline{0.022} \text{ in}
 \end{aligned}$$

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC-107 (Weight operating corroded governs)

Applied Loads

Radial load:	$P_r = 0$	lb_f
Circumferential moment:	$M_c = 0$	$\text{lb}_f\text{-in}$
Circumferential shear:	$V_c = 0$	lb_f
Longitudinal moment:	$M_L = 838.31$	$\text{lb}_f\text{-in}$
Longitudinal shear:	$V_L = 479.03$	lb_f
Torsion moment:	$M_t = 0$	$\text{lb}_f\text{-in}$
Internal pressure:	$P = 0$	psi
Mean shell radius:	$R_m = 11.875$	in
Local shell thickness:	$t = 0.25$	in
Shell yield stress:	$S_y = 16,000$	psi

Maximum stresses due to the applied loads at the leg edge (includes pressure)

$$R_m / t = 11.875 / 0.25 = 47.5$$

$$C_1 = 0.9014, C_2 = 2.778 \text{ in}$$

$$\text{Local circumferential pressure stress} = P \cdot R_i / t = 0 \text{ psi}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i / 2t = 0 \text{ psi}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = -2,151 \text{ psi}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = \pm 3 \cdot S = \pm 43,200 \text{ psi}$$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = -554 \text{ psi}$$

$$\text{Allowable local primary membrane } (P_L) = \pm 1.5 \cdot S = \pm 21,600 \text{ psi}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the leg edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.317	0.1909	0	0	0	0	0	0	0	0
4C*	7.2195	0.1573	0	0	0	0	0	0	0	0
1C	0.1034	0.1189	0	0	0	0	0	0	0	0
2C-1	0.0689	0.1189	0	0	0	0	0	0	0	0
3A*	1.6551	0.1105	0	0	0	0	0	0	0	0
1A	0.087	0.1321	0	0	0	0	0	0	0	0
3B*	5.2076	0.1608	-554	-554	554	554	0	0	0	0
1B-1	0.0337	0.143	-1,597	1,597	1,597	-1,597	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-2,151	1,043	2,151	-1,043	0	0	0	0
Primary membrane circumferential stress*			-554	-554	554	554	0	0	0	0
3C*	5.2992	0.1573	0	0	0	0	0	0	0	0
4C*	6.6487	0.1909	0	0	0	0	0	0	0	0
1C-1	0.0785	0.1633	0	0	0	0	0	0	0	0
2C	0.0458	0.1633	0	0	0	0	0	0	0	0
4A*	2.4608	0.1105	0	0	0	0	0	0	0	0
2A	0.0399	0.1701	0	0	0	0	0	0	0	0
4B*	1.9064	0.1608	-333	-333	333	333	0	0	0	0
2B-1	0.0386	0.1851	-1,413	1,413	1,413	-1,413	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-1,746	1,080	1,746	-1,080	0	0	0	0
Primary membrane longitudinal stress*			-333	-333	333	333	0	0	0	0
Shear from M_t			0	0	0	0	0	0	0	0

Circ shear from V_c	0	0	0	0	0	0	0	0
Long shear from V_L	0	0	0	0	-172	-172	172	172
Total Shear stress	0	0	0	0	-172	-172	172	172
Combined stress (P_L+P_b+Q)	-2,151	1,080	2,151	-1,080	344	344	344	344

Note: * denotes primary stress.



Eden Cryogenics LLC
8449 Rausch Drive
Plain City, Ohio 43064
TRL-19788
1977B
1979B

Pressure Test Report

Work Order: BC 02128 Drawing Number: 5820-01
Customer: FERMILAB 5820-02
Description: 5820-01, 5820-02, 5820-03 - INNER vessels
Project Engineer: Jim M. Test Performed By: R. Basham LII
Specification: BC 101-070-002 Disposition By: R. Basham LII

Parameters: Gauge S/N G-14 NEXT call 8/18/10
Pneumatic: ☒ Hydrostatic: ☐ PSI: 188 TEST Time (min.): See Below
165 Design

Conclusion:

TIE all 3 vessels Together and pressurize to
188 psi, Reduce to 165 psi and Visually Inspect,
Bubble test all vessels

5820-01 START 12:43^{PM} FINISH
Each 188 psi 1:08^{PM}
165 psi Bubble test 1:13^{PM} - 1:28^{PM}

5820-02 START 12:43^{PM} FINISH 188 psi 1:08^{PM}
165 psi Bubble TEST 1:13^{PM} - 1:28^{PM}

5820-03 START 12:43^{PM} FINISH 188 psi 1:08^{PM}
165 psi Bubble test 1:13^{PM} - 1:28^{PM}

NO Reportable INDICATIONS
Accept (Qty-3)

Back Security AT HSB
3/25/10

Signature: Randy Basham LII

Date: 3/25/10



Eden Cryogenics LLC
8445 Rausch Drive
Plain City, Ohio 43064

Penetrant Inspection Report

Work Order: BC 02/28 Drawing Number: 5820-01
Contract Number: Fermi Lab Traveler # 1978 B #1
Weld Description: inner Nestel 5T-3-S, 12-16
Project Engineer: ~~P. Kazmierczak~~ JHM Test Performed By: E. Meadows
Specification: BC 101-003-101 Disposition By: E. Meadows

Penetrant: Magnaflux SKL-SP 10 MIN Batch No: 07LIK
Cleaner: Magnaflux SKC-S 5 MIN Batch No: 08H05K
Developer: Magnaflux SKD-S2 15 MIN Batch No: 09E06K

Conclusion:

JT- 3-S, 12-16 / single PASS /

NO REPORTABLE INDICATION FOUND AT TIME OF INSPECTION Edm

ACCEPT

Signature: E. Meadows ^{LE}

Date: 3-11-10

B8 3/25/10



Combination Pressure/Mass Spectrometer Leak Test
Inspection Data Sheet

Eden Cryogenics LLC
8445 Rausch Drive
Plain City, Ohio 43064

Free - 2010 - 03

Work Order #: Bc-20128

Eden Specification #: Bc-101-050-010 Test Equipment: MS-410 #1 / G-14

Calibrated Leak Serial No. / Rate: 0894 / 1.9 X 10⁻⁸ cc/sec

Test Article: 5800-03 Car Purifier

EVENT	START	END	MASS SPEC INDICATION *	MASS SPEC LEAK**	TEST PRESS, HOLD TIME, COMMENTS	DECAY	
						NO	YES
1			1.9 X 10 ⁻⁸ cc/sec				
2			0.1 X 10 ⁻¹⁰ cc/sec				
3			2.5 X 10 ⁻⁹ cc/sec				
4	12:43	12:48	2.5 X 10 ⁻⁹ cc/sec				
5	12:49	12:51	2.0 X 10 ⁻⁹ cc/sec		475 psi held for 2 min		✓
5	12:52	12:54	2.0 X 10 ⁻⁹ cc/sec		94 psi		✓
5	12:55	12:57	2.0 X 10 ⁻⁹ cc/sec		1411 psi		✓
5	12:58	1:08	2.0 X 10 ⁻⁹ cc/sec		165 psi hold 10 min		✓
6	1:09	1:11	2.0 X 10 ⁻⁹ cc/sec		Reduce to 150 psi		✓
8	1:14	1:19	2.1 X 10 ⁻⁹ cc/sec		Spray 2 min, Set for 5 min		✓
9	1:20	1:21	2.1 X 10 ⁻⁹ cc/sec				
10	1:22	1:23	1.9 X 10 ⁻⁸ cc/sec				
Mass Spectrometer		Accept (No Reportable Indications)		Pressurization		Accept (No Reportable Indications)	
Leak Test:		Reject		Leak Test:		Reject	

EVENTS

1	Calibrated Leak (start)	5	Internal Piping Pressure (PSI)	9	Final Reading
2	Minimum Detectable Leak (MDL)	6	Visually Inspect Exposed Inner Line Welds	10	Calibrated Leak (finish)
3	Background Helium (after tie in)	7	Bubble Test Exposed Inner Line Welds		
4	Spray Oper Vacuum Enclosure	8	Spray Bagged System		

* Actual Reading (Maximum Acceptable Leak Rate: 1 x 10⁻⁹ std. cc/sec A.E.)

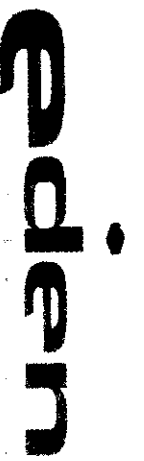
** Difference between MDL (background) indication and present reading

Authorized Signature

[Signature]

Date

6/15/10



Combination Pressure/Mass Spectrometer Leak Test
Inspection Data Sheet

Eden Cryogenics LLC
8445 Rausch Drive
Plain City, Ohio 43064

INAVCCMT 2010-02

Work Order #

BC - 02128

Eden Specification #

BC101-050-010 (Ref) Test Equipment

MS-407

Next cal 8-15-11

Calibrated Leak Serial No. / Rate

5/2 08-94 1.6 x 10⁻⁹ A.E. @ 21°C

Test Article

550002 LAR Passiflex vessel

EVENT	START	END	MASS SPEC INDICATION *	MASS SPEC LEAK **	TEST PRESS, HOLD TIME, COMMENTS	DECAY	
						NO	YES
1	7:48 ⁰⁰	7:51 ⁰⁰	1.5 x 10 ⁻⁸ A.E.				
2	7:51 ⁰⁰	7:53 ⁰⁰	0.5 x 10 ⁻¹⁰ A.E.				
3	7:53 ⁰⁰	8:00 ⁰⁰	5.3 x 10 ⁻⁹ A.E.				
4	8:00 ⁰⁰	8:10 ⁰⁰	2.6 x 10 ⁻⁹ A.E.				
5	8:10 ⁰⁰	8:16 ⁰⁰	1.0 x 10 ⁻⁹ A.E.		41.25 PSI - Held 2 min.		
	8:16 ⁰⁰	8:19 ⁰⁰	0.8 x 10 ⁻⁹ A.E.		82.50 PSI - "		
	8:19 ⁰⁰	8:22 ⁰⁰	0.7 x 10 ⁻⁹ A.E.		125.75 PSI - "		
	8:22 ⁰⁰	8:33 ⁰⁰	5.5 x 10 ⁻¹⁰ A.E.		165.00 PSI - Held 10 min.		
5	8:33 ⁰⁰	8:34 ⁰⁰	5.3 x 10 ⁻¹⁰ A.E.		Reduce to design (isopd)		
6, 7	8:34 ⁰⁰	8:40 ⁰⁰	5.0 x 10 ⁻¹⁰ A.E.		Visual + Bubble Test		
8	8:50 ⁰⁰	8:55 ⁰⁰	2.8 x 10 ⁻¹⁰ A.E.		(Spray / mt. sit 4 min.)		
9	8:55 ⁰⁰	8:56 ⁰⁰	2.8 x 10 ⁻¹⁰ A.E.				
10	8:56 ⁰⁰	8:59 ⁰⁰	1.8 x 10 ⁻¹⁰ A.E.				
Mass Spectrometer		<input checked="" type="checkbox"/> Accept (No Reportable Indications)	Pressurization		<input checked="" type="checkbox"/> Accept (No Reportable Indications)		
Leak Test		<input type="checkbox"/> Reject	Leak Test		<input type="checkbox"/> Reject		

EVENTS

1	Calibrated Leak (start)	5	Internal Piping Pressure (PSI)	9	Final Reading
2	Minimum Detectable Leak (MDL)	6	Visually Inspect Exposed Inner Line Welds	10	Calibrated Leak (finish)
3	Background Helium (after tie in)	7	Bubble Test Exposed Inner Line Welds		
4	Spray Open Vacuum Enclosure	8	Spray Bagged System		

* Actual Reading (Maximum Acceptable Leak Rate: 1 x 10⁻⁹ std. cc/sec A.E.)

** Difference between MDL (background) indication and present reading

Authorized Signature

E. Boehman III

Date

6-24-10



Eden Cryogenics LLC
8445 Rausch Drive
Plain City, Ohio 43064

Penetrant Inspection Report

Work Order: BC 02128 Drawing Number: 5820-02
Contract Number: Femi lab Traveler # 1978^{ed} B #2
Weld Description: inner vessel JT- 3-5, 12-16
Project Engineer: P. Kazmierczak JHM Test Performed By: E. Meadows
Specification: BC 101- 003 -101 Disposition By: E. Meadows

Penetrant: Magnaflux SKL-SP 10 MIN Batch No: 07LIK
Cleaner: Magnaflux SKC-S 5 MIN Batch No: 08H05K
Developer: Magnaflux SKD-S2 15 MIN Batch No: 09E06K

Conclusion:

JT- 3 — 5, 12 — 16 / Single PASS /

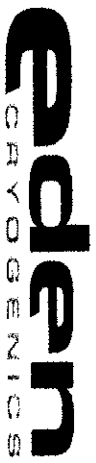
NO REPORTABLE INDICATION FOUND AT TIME OF INSPECTION elm

ACCEPT

Signature: E. Meadows EH

Date: 3-12-10

3/25/10



Combination Pressure/Mass Spectrometer Leak Test
Inspection Data Sheet

Eden Cryogenics LLC
8445 Rausch Drive
Plain City, Ohio 43064

1 real 10/10-01

Work Order #:

PC-02188

Eden Specification #:

PC-101-050-014 (Reg) Test Equipment:

MS-40#1/6-14

Calibrated Leak Serial No. / Rate:

0894 / 1.5X10⁻⁸ A/E

Test Article:

5800-01 LAR Porific

EVENT	START	END	MASS SPEC INDICATION *	MASS SPEC LEAK**	TEST PRESS, HOLD TIME, COMMENTS	DECAY	
						NO	YES
1			1.5 X 10 ⁻⁸ A/E				
2			0.1 X 10 ⁻¹⁰ A/E				
3			2.0 X 10 ⁻¹⁰ A/E				
4	10:46	10:52	2.0 X 10 ⁻¹⁰ A/E				
5	10:55	10:57	2.0 X 10 ⁻¹⁰ A/E		47 psi. Held 2 min		✓
5	10:59	11:04	3.0 X 10 ⁻¹⁰ A/E		94 psi		✓
5	11:05	11:07	2.0 X 10 ⁻¹⁰ A/E		141 psi		✓
5	11:08	11:10	2.0 X 10 ⁻¹⁰ A/E		165 psi. Held 10 min		✓
6	11:13	11:23	2.0 X 10 ⁻¹⁰ A/E		Reduce to 150 psi		✓
6	11:24	11:29	2.0 X 10 ⁻¹⁰ A/E		Spread 2 min, Set 5 min		✓
9			11:29	2.0 X 10 ⁻¹⁰ A/E			
10			11:32	1.5 X 10 ⁻⁸			
Mass Spectrometer		✓	Accept (No Reportable Indications)	Pressurization	✓	Accept (No Reportable Indications)	
Leak Test:		Reject		Leak Test:		Reject	

EVENTS

1	Calibrated Leak (start)	5	Internal Piping Pressure (PSI)	9	Final Reading
2	Minimum Detectable Leak (MDL)	6	Visually Inspect Exposed Inner Line Welds	10	Calibrated Leak (finish)
3	Background Helium (after tie in)	7	Bubble Test Exposed Inner Line Welds		
4	Spray Open Vacuum Enclosure	8	Spray Bagged System		

* Actual Reading (Maximum Acceptable Leak Rate: 1 x 10⁻⁹ std. cc/sec A.E.)

** Difference between MDL (background) indication and present reading

Authorized Signature

R. Baabem CII 6/10/10

Date

6/10/10



JRW # 1979

Eden Cryogenics LLC
8445 Rausch Drive
Plain City, Ohio 43064

Penetrant Inspection Report

Work Order: RC-02128 Drawing Number: BC-02128-5820-03
Contract Number: FERMILAB
Weld Description: See Below
Project Engineer: J. M. Test Performed By: M. LAPOKTA
Specification: BC101-003-101 Disposition By: R. BASHAM LII

Penetrant: Magnaflux SKL-SP Batch No: 07L11K 06820
Cleaner: Magnaflux SKC-S Batch No: 08H05K 005352
Developer: Magnaflux SKD-S2 Batch No: 09E06K 07683

Conclusion: 2128-03 vesselJT-02128-5820-3,4,5,12,13,14,15,16 Single PassCLEANER 5 minPENETRANT 10 minCLEANER 5 minDEVELOPER 15 minRESULTS; NO REPORTABLE INDICATIONS, ACCEPT ALL JOINTSSignature: R. Basham LII3/11/10Date: 3/11/10BS 3/25/10

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{Relief valve calculations for the fire conditions for the LAPD filter vessels}

{Considers both radiation between surfaces and convection between surfaces}

L_gap = 0.009525 {m, gap between the filter vessel wall and the radiation shields, vacuum jacket ID is 23.5" and filter vessel OD of 12.75" OD, gap was measured as roughly 3/8 inch}

L_gap_inches = 0.009525*39.37 {convert gap from meters to inches}

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qrad_12 = As*sigma*(T_1^4 - T_2^4)/(1/epsilon_1 + 1/epsilon_2 - 1) {W, radiation exchange between the vacuum jacket and the outer shield}

qrad_12+ qconv_12 = q_total {W, total heat flow from outer to inner vessel}

{convection between the vacuum jacket and the outer shield}

Ra_L12= g*Beta12*(T_1-T_2)*L12^3/ (alpha12*nu12) {Rayleigh Number}

Beta12 = 1 / T_film12 {1/K, volumetric thermal expansion coefficient}

T_film12 = (T_1+ T_2)/2 {K, average temperature of the two enclosure surfaces used for property evaluation}

L12= L_inches12/39.37 {m, length of the gap between the two surfaces}

L_inches12 = 0.375 {in, length of the gap between the two surfaces}

alpha12 = k12 / (rho12*Cp12) {m^2/s, thermal diffusivity, thermal diffusivity relationship}

mu12 = rho12*nu12 {kg/ s*m, relationship between dynamic and kinematic viscosity }

k12 = Conductivity(Air,T=T_film12) {W/m*K, thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

rho12= Density(Air,T=T_film12,P=Patm12) {kg/m^3, density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

Patm12= 1.01325 {bar, pressure in the vacuum jacket}

Cp12 =Cp(Air,T=T_film12) {J/kg-K, specific heat of the air in the vacuum jacket at constant pressure}

mu12 =Viscosity(Air,T=T_film12) {kg/ s*m, viscosity }

H_over_L_ration12 = H_inches12/ L_inches12 {dimensionless, ratio of the cavity height H to the cavity gap L}

H_inches12 = 65 {inches, height of the cavity}

H12= H_inches12/39.37 {meters, height of the cavity}

Pr12= nu12/alpha12 {Prandtl number, dimensionless, ratio of the momentum and thermal diffusivities, nu over alpha}

Nus_12 = hbar12*L12/k12 {Nusselt number, dimensionless temperature gradient at the surface}

qconv_12 = hbar12*As*(T_1-T_2) {W, convective heat transfer rate between opposite cavity walls}

{equation 4.91 Handbook of Heat Transfer 3rd Edition}

Nus_12= (1 + (((0.0665*Ra_L12^(1/3)) / (1+(9000/Ra_L12)^(1.4)))^2)^(1/2) {correlation for Pr~0.7, validated for Ra < 10^6 and 40 < H/L < 110, H/L is computed as 173 so its out of range, Shewen et al }

$$\text{Nus}_{12_check_horizontal} = 0.069 * (\text{Ra}_{L12}^{1/3}) * (\text{Pr}_{12}^{0.074})$$

$$\text{q}_{rad_23} = \text{As} * \sigma * (T_{2,4} - T_{3,4}) / (1/\epsilon_2 + 1/\epsilon_3 - 1)$$

$$\text{q}_{rad_23} + \text{q}_{conv_23} = \text{q}_{total} \quad \{W, \text{total heat flow from outer to inner vessel}\}$$

$$\quad \{\text{convection between radiation shields}\}$$

$$\text{Ra}_{L23} = g * \beta_{23} * (T_2 - T_3) * L_{23}^3 / (\alpha_{23} * \nu_{23}) \quad \{\text{Rayleigh Number}\}$$

$$\beta_{23} = 1 / T_{film23} \quad \{1/K, \text{volumetric thermal expansion coefficient}\}$$

$$T_{film23} = (T_2 + T_3) / 2 \quad \{K, \text{average temperature of the two enclosure surfaces used for property evaluation}\}$$

$$L_{23} = L_{inches23} / 39.37 \quad \{m, \text{length of the gap between the two surfaces}\}$$

$$L_{inches23} = 0.375 \quad \{in, \text{length of the gap between the two surfaces}\}$$

$$\alpha_{23} = k_{23} / (\rho_{23} * C_{p23}) \quad \{m^2/s, \text{thermal diffusivity, thermal diffusivity relationship}\}$$

$$\mu_{23} = \rho_{23} * \nu_{23} \quad \{kg/s * m, \text{relationship between dynamic and kinematic viscosity}\}$$

$$k_{23} = \text{Conductivity}(\text{Air}, T=T_{film23}) \quad \{W/m * K, \text{thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces}\}$$

$$\rho_{23} = \text{Density}(\text{Air}, T=T_{film23}, P=P_{atm23}) \quad \{kg/m^3, \text{density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces}\}$$

$$P_{atm23} = 1.01325 \quad \{bar, \text{pressure in the vacuum jacket}\}$$

$$C_{p23} = C_p(\text{Air}, T=T_{film23}) \quad \{J/kg * K, \text{specific heat of the air in the vacuum jacket at constant pressure}\}$$

$$\mu_{23} = \text{Viscosity}(\text{Air}, T=T_{film23}) \quad \{kg/s * m, \text{viscosity}\}$$

$$H_{over_L_ration23} = H_{inches23} / L_{inches23} \quad \{\text{dimensionless, ratio of the cavity height } H \text{ to the cavity gap } L\}$$

$$H_{inches23} = 65 \quad \{inches, \text{height of the cavity}\}$$

$$H_{23} = H_{inches23} / 39.37 \quad \{meters, \text{height of the cavity}\}$$

$$\text{Pr}_{23} = \nu_{23} / \alpha_{23} \quad \{\text{Prandtl number, dimensionless, ratio of the momentum and thermal diffusivities, } \nu \text{ over } \alpha\}$$

$$\text{Nus}_{23} = \bar{h}_{23} * L_{23} / k_{23} \quad \{\text{Nusselt number, dimensionless temperature gradient at the surface}\}$$

$$\text{q}_{conv_23} = \bar{h}_{23} * \text{As} * (T_2 - T_3) \quad \{W, \text{convective heat transfer rate between opposite cavity walls}\}$$

$$\quad \{\text{equation 4.91 Handbook of Heat Transfer 3rd Edition}\}$$

$$\text{Nus}_{23} = (1 + ((0.0665 * \text{Ra}_{L23}^{1/3}) / (1 + (9000 / \text{Ra}_{L23})^{1.4}))^{1/2})^{1/2} \quad \{\text{correlation for } Pr \sim 0.7, \text{ validated for } Ra < 10^6 \text{ and } 40 < H/L < 110, H/L \text{ is computed as } 173 \text{ so its out of range}\}$$

$$\text{q}_{rad_34} = \text{As} * \sigma * (T_{3,4} - T_{4,4}) / (1/\epsilon_3 + 1/\epsilon_4 - 1)$$

$$q_{rad_34} + q_{conv_34} = q_{total} \quad \{W, \text{ total heat flow from outer to inner vessel}\}$$

{convection between radiation shields}

$$Ra_{L34} = g \cdot \beta_{34} \cdot (T_3 - T_4) \cdot L_{34}^3 / (\alpha_{34} \cdot \nu_{34}) \quad \{\text{Rayleigh Number}\}$$

$$\beta_{34} = 1 / T_{film34} \quad \{1/K, \text{ volumetric thermal expansion coefficient}\}$$

$$T_{film34} = (T_3 + T_4) / 2 \quad \{K, \text{ average temperature of the two enclosure surfaces used for property evaluation}\}$$

$$L_{34} = L_{inches34} / 39.37 \quad \{m, \text{ length of the gap between the two surfaces}\}$$

$$L_{inches34} = 0.375 \quad \{in, \text{ length of the gap between the two surfaces}\}$$

$$\alpha_{34} = k_{34} / (\rho_{34} \cdot C_{p34}) \quad \{m^2/s, \text{ thermal diffusivity, thermal diffusivity relationship}\}$$

$$\mu_{34} = \rho_{34} \cdot \nu_{34} \quad \{kg/s \cdot m, \text{ relationship between dynamic and kinematic viscosity}\}$$

$$k_{34} = \text{Conductivity}(\text{Air}, T=T_{film34}) \quad \{W/m \cdot K, \text{ thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces}\}$$

$$\rho_{34} = \text{Density}(\text{Air}, T=T_{film34}, P=P_{atm34}) \quad \{kg/m^3, \text{ density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces}\}$$

$$P_{atm34} = 1.01325 \quad \{bar, \text{ pressure in the vacuum jacket}\}$$

$$C_{p34} = \text{Cp}(\text{Air}, T=T_{film34}) \quad \{J/kg \cdot K, \text{ specific heat of the air in the vacuum jacket at constant pressure}\}$$

$$\mu_{34} = \text{Viscosity}(\text{Air}, T=T_{film34}) \quad \{kg/s \cdot m, \text{ viscosity}\}$$

$$H_{over_L_ration34} = H_{inches34} / L_{inches34} \quad \{\text{dimensionless, ratio of the cavity height } H \text{ to the cavity gap } L\}$$

$$H_{inches34} = 65 \quad \{inches, \text{ height of the cavity}\}$$

$$H_{34} = H_{inches12} / 39.37 \quad \{meters, \text{ height of the cavity}\}$$

$$Pr_{34} = \nu_{34} / \alpha_{34} \quad \{\text{Prandtl number, dimensionless, ratio of the momentum and thermal diffusivities, } \nu \text{ over } \alpha\}$$

$$Nus_{34} = \bar{h}_{34} \cdot L_{34} / k_{34} \quad \{\text{Nusselt number, dimensionless temperature gradient at the surface}\}$$

$$q_{conv_34} = \bar{h}_{34} \cdot A_s \cdot (T_3 - T_4) \quad \{W, \text{ convective heat transfer rate between opposite cavity walls}\}$$

{equation 4.91 Handbook of Heat Transfer 3rd Edition}

$$Nus_{34} = \left(1 + \left(\frac{(0.0665 \cdot Ra_{L34}^{1/3})}{(1 + (9000/Ra_{L34})^{1.4})} \right)^2 \right)^{1/2} \quad \{\text{correlation for } Pr \sim 0.7, \text{ validated for } Ra < 10^6 \text{ and } 40 < H/L < 110, H/L \text{ is computed as } 173 \text{ so its out of range}\}$$

{-----}

$$q_{rad_45} = A_s \cdot \sigma \cdot (T_4^4 - T_5^4) / (1/\epsilon_4 + 1/\epsilon_5 - 1)$$

$$q_{rad_45} + q_{conv_45} = q_{total} \quad \{W, \text{ total heat flow from outer to inner vessel}\}$$

{convection between radiation shields}

$$Ra_{L45} = g \cdot \beta_{45} \cdot (T_4 - T_5) \cdot L_{45}^3 / (\alpha_{45} \cdot \nu_{45}) \quad \{\text{Rayleigh Number}\}$$

$$\beta_{45} = 1 / T_{film45} \quad \{1/K, \text{ volumetric thermal expansion coefficient}\}$$

$$T_{\text{film45}} = (T_4 + T_5)/2 \quad \{K, \text{average temperature of the two enclosure surfaces used for property evaluation}\}$$

$$L_{45} = L_{\text{inches12}}/39.37 \quad \{m, \text{length of the gap between the two surfaces}\}$$

$$L_{\text{inches45}} = 0.375 \quad \{in, \text{length of the gap between the two surfaces}\}$$

$$\alpha_{45} = k_{45}/(\rho_{45} \cdot C_{p45}) \quad \{m^2/s, \text{thermal diffusivity, thermal diffusivity relationship}\}$$

$$\mu_{45} = \rho_{45} \cdot \nu_{45} \quad \{kg/s \cdot m, \text{relationship between dynamic and kinematic viscosity}\}$$

$$k_{45} = \text{Conductivity}(\text{Air}, T=T_{\text{film45}}) \quad \{W/m \cdot K, \text{thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces}\}$$

$$\rho_{45} = \text{Density}(\text{Air}, T=T_{\text{film45}}, P=P_{\text{atm45}}) \quad \{kg/m^3, \text{density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces}\}$$

$$P_{\text{atm45}} = 1.01325 \quad \{bar, \text{pressure in the vacuum jacket}\}$$

$$C_{p45} = \text{Cp}(\text{Air}, T=T_{\text{film45}}) \quad \{J/kg \cdot K, \text{specific heat of the air in the vacuum jacket at constant pressure}\}$$

$$\mu_{45} = \text{Viscosity}(\text{Air}, T=T_{\text{film45}}) \quad \{kg/s \cdot m, \text{viscosity}\}$$

$$H_{\text{over}_L\text{ration45}} = H_{\text{inches45}}/L_{\text{inches45}} \quad \{\text{dimensionless, ratio of the cavity height } H \text{ to the cavity gap } L\}$$

$$H_{\text{inches45}} = 65 \quad \{inches, \text{height of the cavity}\}$$

$$H_{45} = H_{\text{inches12}}/39.37 \quad \{meters, \text{height of the cavity}\}$$

$$Pr_{45} = \nu_{45}/\alpha_{45} \quad \{Prandtl \text{ number, dimensionless, ratio of the momentum and thermal diffusivities, } \nu \text{ over } \alpha\}$$

$$Nus_{45} = \bar{h}_{45} \cdot L_{45}/k_{45} \quad \{Nusselt \text{ number, dimensionless temperature gradient at the surface}\}$$

$$q_{\text{conv}_45} = \bar{h}_{45} \cdot A_s \cdot (T_4 - T_5) \quad \{W, \text{convective heat transfer rate between opposite cavity walls}\}$$

{equation 4.91 Handbook of Heat Transfer 3rd Edition}

$$Nus_{45} = (1 + ((0.0665 \cdot Ra_{L45}^{1/3}) / (1 + (9000/Ra_{L45})^{1.4}))^{1/2})^{1/2} \quad \{\text{correlation for } Pr \sim 0.7, \text{ validated for } Ra < 10^6 \text{ and } 40 < H/L < 110, H/L \text{ is computed as } 173 \text{ so its out of range}\}$$

$$\{ \text{-----} \}$$

$$q_{\text{rad}_56} = A_s \cdot \sigma \cdot (T_5^4 - T_6^4) / (1/\epsilon_5 + 1/\epsilon_6 - 1)$$

$$q_{\text{rad}_56} + q_{\text{conv}_56} = q_{\text{total}} \quad \{W, \text{total heat flow from outer to inner vessel}\}$$

{convection between radiation shields}

$$Ra_{L56} = g \cdot \beta_{56} \cdot (T_5 - T_6) \cdot L_{56}^3 / (\alpha_{56} \cdot \nu_{56}) \quad \{Rayleigh \text{ Number}\}$$

$$\beta_{56} = 1/T_{\text{film56}} \quad \{1/K, \text{volumetric thermal expansion coefficient}\}$$

$$T_{\text{film56}} = (T_5 + T_6)/2 \quad \{K, \text{average temperature of the two enclosure surfaces used for property evaluation}\}$$

$$L_{56} = L_{\text{inches12}}/39.37 \quad \{m, \text{length of the gap between the two surfaces}\}$$

$$L_{\text{inches56}} = 0.375 \quad \{in, \text{length of the gap between the two surfaces}\}$$

$$\alpha_{56} = k_{56}/(\rho_{56} \cdot C_{p56}) \quad \{m^2/s, \text{thermal diffusivity, thermal diffusivity relationship}\}$$

$\mu_{56} = \rho_{56} \cdot \nu_{56}$ {kg/ s*m, relationship between dynamic and kinematic viscosity }

$k_{56} = \text{Conductivity}(\text{Air}, T=T_{\text{film}56})$ {W/m*K, thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

$\rho_{56} = \text{Density}(\text{Air}, T=T_{\text{film}56}, P=Patm56)$ {kg/m³, density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

$Patm56 = 1.01325$ {bar, pressure in the vacuum jacket}

$Cp_{56} = Cp(\text{Air}, T=T_{\text{film}56})$ {J/kg-K, specific heat of the air in the vacuum jacket at constant pressure}

$\mu_{56} = \text{Viscosity}(\text{Air}, T=T_{\text{film}56})$ {kg/ s*m, viscosity }

$H_{\text{over}_L\text{ration}56} = H_{\text{inches}56} / L_{\text{inches}56}$ {dimensionless, ratio of the cavity height H to the cavity gap L}

$H_{\text{inches}56} = 65$ {inches, height of the cavity}

$H_{56} = H_{\text{inches}56} / 39.37$ {meters, height of the cavity}

$Pr_{56} = \mu_{56} / \alpha_{56}$ {Prandtl number, dimensionless, ratio of the momentum and thermal diffusivities, nu over alpha}

$Nu_{56} = h_{56} \cdot L_{56} / k_{56}$ {Nusselt number, dimensionless temperature gradient at the surface}

$q_{\text{conv}_56} = h_{56} \cdot A_s \cdot (T_5 - T_6)$ {W, convective heat transfer rate between opposite cavity walls}

{equation 4.91 Handbook of Heat Transfer 3rd Edition}

$Nu_{56} = (1 + ((0.0665 \cdot Ra_{L56}^{1/3}) / (1 + (9000 / Ra_{L56})^{1.4}))^{1/2})^{1/2}$ {correlation for $Pr \sim 0.7$, validated for $Ra < 10^6$ and $40 < H/L < 110$, H/L is computed as 173 so its out of range }

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$q_{\text{rad}_67} = A_s \cdot \sigma \cdot (T_6^4 - T_7^4) / (1/\epsilon_6 + 1/\epsilon_7 - 1)$

$q_{\text{rad}_67} + q_{\text{conv}_67} = q_{\text{total}}$ {W, total heat flow from outer to inner vessel}

{convection between radiation shields}

$Ra_{L67} = g \cdot \beta_{67} \cdot (T_6 - T_7) \cdot L_{67}^3 / (\alpha_{67} \cdot \nu_{67})$ {Rayleigh Number}

$\beta_{67} = 1 / T_{\text{film}67}$ {1/K, volumetric thermal expansion coefficient}

$T_{\text{film}67} = (T_6 + T_7) / 2$ {K, average temperaure of the two enclosure surfaces used for property evaluation}

$L_{67} = L_{\text{inches}12} / 39.37$ {m, length of the gap between the two surfaces}

$L_{\text{inches}67} = 0.375$ {in, length of the gap between the two surfaces}

$\alpha_{67} = k_{67} / (\rho_{67} \cdot Cp_{67})$ {m²/s, thermal diffusivity, thermal dffusivity relationship}

$\mu_{67} = \rho_{67} \cdot \nu_{67}$ {kg/ s*m, relationship between dynamic and kinematic viscosity }

$k_{67} = \text{Conductivity}(\text{Air}, T=T_{\text{film}67})$ {W/m*K, thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

$\rho_{67} = \text{Density}(\text{Air}, T=T_{\text{film}67}, P=Patm67)$ {kg/m³, density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

Patm67= 1.01325 {bar, pressure in the vacuum jacket}

Cp67 =Cp(Air,T=T_film67) {J/kg-K, specific heat of the air in the vacuum jacket at constant pressure}

mu67 =Viscosity(Air,T=T_film67) {kg/ s*m, viscosity }

H_over_L_ration67 = H_inches67/ L_inches67 {dimensionless, ratio of the cavity height H to the cavity gap L}

H_inches67 = 65 {inches, height of the cavity}

H67= H_inches67/39.37 {meters, height of the cavity}

Pr67= nu67/alpha67 {Prandtl number, dimensionless, ratio of the momentum and thermal diffusivities, nu over alpha}

Nus_67 = hbar67*L67/k67 {Nusselt number, dimensionless temperature gradient at the surface}

qconv_67 = hbar67*As*(T_6-T_7) {W, convective heat transfer rate between opposite cavity walls}

{equation 4.91 Handbook of Heat Transfer 3rd Edition}

Nus_67= (1 + (((0.0665*Ra_L67^(1/3)) / (1+(9000/Ra_L67)^1.4))^2))^(1/2) {correlation for Pr~0.7, validated for Ra < 10^6 and 40 < H/L < 110, H/L is computed as 173 so its out of range }

{-----}

qrad_78 = As*sigma*(T_7^4 - T_8^4)/(1/epsilon_7 + 1/epsilon_8 - 1) {radiation exchange between the inner shield and the inner vessel}

qrad_78+ qconv_78 = q_total {W, total heat flow from outer to inner vessel}

Ra_L78 = g*Beta78*(T_7-T_8)*L78^3/ (alpha78*nu78) {Rayleigh Number}

g = 9.8 {gravitational acceleration m/s^2}

Beta78 = 1 / T_film78 {1/K, volumetric thermal expansion coefficient}

T_film78 = (T_7 + T_8)/2 {K, average tempereature of the two enclosure surfaces used for property evaluation}

L78 = L_inches78/39.37 {m, length of the gap between the two surfaces}

L_inches78 = 3.125 {in, length of the gap between the two surfaces}

alpha78 = k78 / (rho78*Cp78) {thermal diffusivity, m2/s, evaluated for air at ambient pressure and Tf }

mu78 = rho78*nu78 {viscosity kg/ s* m}

k78 = Conductivity(Air,T=T_film78) {thermal conductivity of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

rho78 = Density(Air,T=T_film78,P=Patm78) {density of the air in the vacuum space, evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces }

Patm78 = 1.01325 {bar, pressure in the vacuum jacket}

$Cp_{78} = Cp(Air, T=T_{film78})$ {J/kg-K, specific heat of the air in the vacuum jacket at constant pressure}

$\mu_{78} = Viscosity(Air, T=T_{film78})$ {kg/s*m, viscosity}

$H_{over_L_ration78} = H_{inches78} / L_{inches78}$ {dimensionless, ratio of the cavity height H to the cavity gap L}

$H_{inches78} = 65$ {inches, height of the cavity}

$H_{78} = H_{inches78}/39.37$ {meters, height of the cavity}

$Pr_{78} = \nu_{78}/\alpha_{78}$ {Prandtl number, dimensionless, ratio of the momentum and thermal diffusivities, nu over alpha}

$Nus_{78} = hbar_{78} * L_{78} / k_{78}$ {Nusselt number, dimensionless temperature gradient at the surface}

$q_{conv_78} = hbar_{78} * A_s * (T_{7-} - T_{8-})$ {W, convective heat transfer rate between opposite cavity walls}

$A_s = 4.132$ {m² The surface area A for all calculations was taken as the surface area of a cylinder (including the top and bottom) whose outside diameter matches the inner diameter of the vacuum jacket. This is conservative because the surface area of the radiation shields and the inner vessel is significantly less than that of the vacuum jacket. }

$Nus_{78} = 0.046 * Ra_{L78}^{1/3}$ {Incropera and Dewitt 4th edition equation 9.53} { $Ra_L = 4.3E7$. $H/L = 21$, $Pr = 0.7$, applicable $1 < H/L < 40$, $10^6 < Ra_L < 10^9$ Ra_L , slightly out of the Pr range of $1 < Pr < 2E4$ }

$Nus_{78_check_horizontal} = 0.069 * (Ra_{L78}^{1/3}) * (Pr_{78}^{0.074})$

{-----}

$\sigma = 5.67e-8$ {Stefan-Boltzmann constant W/(m²*K⁴)}

$\epsilon_{1} = 1$ {surface emissivity of the ID of the vacuum jacket}

$\epsilon_{2} = 0.1$ {shield surface emissivity}

$\epsilon_{3} = 0.1$ {shield surface emissivity}

$\epsilon_{4} = 0.1$ {shield surface emissivity}

$\epsilon_{5} = 0.1$ {shield surface emissivity}

$\epsilon_{6} = 0.1$ {shield surface emissivity}

$\epsilon_{7} = 0.1$ {shield surface emissivity}

$\epsilon_{8} = 1$ {surface emissivity of the OD of the inner vessel}

$T_{1} = 922$ {vacuum jacket temperature in K}

$T_{8} = Temperature(Argon, P=8.70, x=0)$ {filter housing temperature in K}

$L_{gap} = 0.009525$

$L_{gap, inches} = 0.009525 \cdot 39.37$

$$q_{\text{rad}12} = A_s \cdot \sigma \cdot \left[\frac{T_1^4 - T_2^4}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} \right]$$

$$q_{\text{rad}12} + q_{\text{conv}12} = q_{\text{total}}$$

$$Ra_{L12} = g \cdot \text{Beta}12 \cdot [T_1 - T_2] \cdot \frac{L12^3}{\alpha12 \cdot \nu12}$$

$$\text{Beta}12 = \frac{1}{T_{\text{film}12}}$$

$$T_{\text{film}12} = \frac{T_1 + T_2}{2}$$

$$L12 = \frac{L_{\text{inches}12}}{39.37}$$

$$L_{\text{inches}12} = 0.375$$

$$\alpha12 = \frac{k12}{\rho12 \cdot C_p12}$$

$$\mu12 = \rho12 \cdot \nu12$$

$$k12 = k \left[\text{'Air'}, T = T_{\text{film}12} \right]$$

$$\rho12 = \rho \left[\text{'Air'}, T = T_{\text{film}12}, P = P_{\text{atm}12} \right]$$

$$P_{\text{atm}12} = 1.01325$$

$$C_p12 = C_p \left[\text{'Air'}, T = T_{\text{film}12} \right]$$

$$\mu12 = \text{Visc} \left[\text{'Air'}, T = T_{\text{film}12} \right]$$

$$H_{\text{over},L,\text{ration}12} = \frac{H_{\text{inches}12}}{L_{\text{inches}12}}$$

$$H_{\text{inches}12} = 65$$

$$H12 = \frac{H_{\text{inches}12}}{39.37}$$

$$Pr12 = \frac{\nu12}{\alpha12}$$

$$Nus_{12} = h_{\text{bar}12} \cdot \frac{L12}{k12}$$

$$q_{\text{conv}12} = h_{\text{bar}12} \cdot A_s \cdot [T_1 - T_2]$$

$$Nus_{12} = \left[1 + \left(\frac{0.0665 \cdot Ra_{L12}^{[1/3]}}{1 + \left[\frac{9000}{Ra_{L12}} \right]^{1.4}} \right)^2 \right]^{[1/2]}$$

$$\text{Nus}_{12,\text{check,horizontal}} = 0.069 \cdot \text{Ra}_{L12}^{1/3} \cdot \text{Pr}_{12}^{0.074}$$

$$q_{\text{rad}23} = A_s \cdot \sigma \cdot \left[\frac{T_2^4 - T_3^4}{\frac{1}{\epsilon_2} + \frac{1}{\epsilon_3} - 1} \right]$$

$$q_{\text{rad}23} + q_{\text{conv}23} = q_{\text{total}}$$

$$\text{Ra}_{L23} = g \cdot \text{Beta}23 \cdot [T_2 - T_3] \cdot \frac{L23^3}{\alpha23 \cdot \nu23}$$

$$\text{Beta}23 = \frac{1}{T_{\text{film}23}}$$

$$T_{\text{film}23} = \frac{T_2 + T_3}{2}$$

$$L23 = \frac{L_{\text{inches}23}}{39.37}$$

$$L_{\text{inches}23} = 0.375$$

$$\alpha23 = \frac{k23}{\rho23 \cdot \text{Cp}23}$$

$$\mu23 = \rho23 \cdot \nu23$$

$$k23 = k[\text{'Air'}, T=T_{\text{film}23}]$$

$$\rho23 = \rho[\text{'Air'}, T=T_{\text{film}23}, P=\text{Patm}23]$$

$$\text{Patm}23 = 1.01325$$

$$\text{Cp}23 = \text{Cp}[\text{'Air'}, T=T_{\text{film}23}]$$

$$\mu23 = \text{Visc}[\text{'Air'}, T=T_{\text{film}23}]$$

$$H_{\text{over,L,ration}23} = \frac{H_{\text{inches}23}}{L_{\text{inches}23}}$$

$$H_{\text{inches}23} = 65$$

$$H23 = \frac{H_{\text{inches}23}}{39.37}$$

$$\text{Pr}23 = \frac{\nu23}{\alpha23}$$

$$\text{Nus}_{23} = h_{\text{bar}23} \cdot \frac{L23}{k23}$$

$$q_{\text{conv}23} = h_{\text{bar}23} \cdot A_s \cdot [T_2 - T_3]$$

$$\text{Nus}_{23} = \left[1 + \left(\frac{0.0665 \cdot \text{Ra}_{L23}^{[1/3]}}{1 + \left[\frac{9000}{\text{Ra}_{L23}} \right]^{1.4}} \right)^2 \right]^{[1/2]}$$

$$\text{qrad}_{34} = \text{As} \cdot \sigma \cdot \left[\frac{T_3^4 - T_4^4}{\frac{1}{\varepsilon_3} + \frac{1}{\varepsilon_4} - 1} \right]$$

$$\text{qrad}_{34} + \text{qconv}_{34} = \text{q}_{\text{total}}$$

$$\text{Ra}_{L34} = g \cdot \text{Beta}_{34} \cdot [T_3 - T_4] \cdot \frac{L_{34}^3}{\alpha_{34} \cdot \text{nu}_{34}}$$

$$\text{Beta}_{34} = \frac{1}{T_{\text{film}34}}$$

$$T_{\text{film}34} = \frac{T_3 + T_4}{2}$$

$$L_{34} = \frac{L_{\text{inches}34}}{39.37}$$

$$L_{\text{inches}34} = 0.375$$

$$\alpha_{34} = \frac{k_{34}}{\rho_{34} \cdot \text{Cp}_{34}}$$

$$\mu_{34} = \rho_{34} \cdot \text{nu}_{34}$$

$$k_{34} = \mathbf{k} ['\text{Air}', T = T_{\text{film}34}]$$

$$\rho_{34} = \rho ['\text{Air}', T = T_{\text{film}34}, P = \text{Patm}_{34}]$$

$$\text{Patm}_{34} = 1.01325$$

$$\text{Cp}_{34} = \mathbf{Cp} ['\text{Air}', T = T_{\text{film}34}]$$

$$\mu_{34} = \mathbf{Visc} ['\text{Air}', T = T_{\text{film}34}]$$

$$\text{H}_{\text{over,L,ration}34} = \frac{H_{\text{inches}34}}{L_{\text{inches}34}}$$

$$H_{\text{inches}34} = 65$$

$$H_{34} = \frac{H_{\text{inches}12}}{39.37}$$

$$\text{Pr}_{34} = \frac{\text{nu}_{34}}{\alpha_{34}}$$

$$\text{Nus}_{34} = \text{hbar}_{34} \cdot \frac{L_{34}}{k_{34}}$$

$$\text{qconv}_{34} = \text{hbar}_{34} \cdot \text{As} \cdot [T_3 - T_4]$$

$$\text{Nus}_{34} = \left[1 + \left(\frac{0.0665 \cdot \text{Ra}_{\text{L34}}^{[1/3]}}{1 + \left[\frac{9000}{\text{Ra}_{\text{L34}}} \right]^{1.4}} \right)^2 \right]^{[1/2]}$$

$$\text{qrad}_{45} = \text{As} \cdot \sigma \cdot \left[\frac{T_4^4 - T_5^4}{\frac{1}{\varepsilon_4} + \frac{1}{\varepsilon_5} - 1} \right]$$

$$\text{qrad}_{45} + \text{qconv}_{45} = \text{q}_{\text{total}}$$

$$\text{Ra}_{\text{L45}} = g \cdot \text{Beta}_{45} \cdot [T_4 - T_5] \cdot \frac{\text{L45}^3}{\alpha_{45} \cdot \nu_{45}}$$

$$\text{Beta}_{45} = \frac{1}{T_{\text{film45}}}$$

$$T_{\text{film45}} = \frac{T_4 + T_5}{2}$$

$$\text{L45} = \frac{\text{L}_{\text{inches12}}}{39.37}$$

$$\text{L}_{\text{inches45}} = 0.375$$

$$\alpha_{45} = \frac{k_{45}}{\rho_{45} \cdot \text{Cp}_{45}}$$

$$\mu_{45} = \rho_{45} \cdot \nu_{45}$$

$$k_{45} = \mathbf{k} [\text{'Air'}, T = T_{\text{film45}}]$$

$$\rho_{45} = \rho [\text{'Air'}, T = T_{\text{film45}}, P = \text{Patm45}]$$

$$\text{Patm45} = 1.01325$$

$$\text{Cp}_{45} = \mathbf{Cp} [\text{'Air'}, T = T_{\text{film45}}]$$

$$\mu_{45} = \mathbf{Visc} [\text{'Air'}, T = T_{\text{film45}}]$$

$$\text{H}_{\text{over,L,ration45}} = \frac{\text{H}_{\text{inches45}}}{\text{L}_{\text{inches45}}}$$

$$\text{H}_{\text{inches45}} = 65$$

$$\text{H45} = \frac{\text{H}_{\text{inches12}}}{39.37}$$

$$\text{Pr}_{45} = \frac{\nu_{45}}{\alpha_{45}}$$

$$\text{Nus}_{45} = \text{hbar}_{45} \cdot \frac{\text{L45}}{k_{45}}$$

$$q_{conv45} = hbar45 \cdot A_s \cdot [T_4 - T_5]$$

$$Nus_{45} = \left[1 + \left(\frac{0.0665 \cdot Ra_{L45}^{[1/3]}}{1 + \left[\frac{9000}{Ra_{L45}} \right]^{1.4}} \right)^2 \right]^{[1/2]}$$

$$q_{rad56} = A_s \cdot \sigma \cdot \left[\frac{T_5^4 - T_6^4}{\frac{1}{\epsilon_5} + \frac{1}{\epsilon_6} - 1} \right]$$

$$q_{rad56} + q_{conv56} = q_{total}$$

$$Ra_{L56} = g \cdot \beta_{56} \cdot [T_5 - T_6] \cdot \frac{L56^3}{\alpha_{56} \cdot \nu_{56}}$$

$$\beta_{56} = \frac{1}{T_{film56}}$$

$$T_{film56} = \frac{T_5 + T_6}{2}$$

$$L56 = \frac{L_{inches12}}{39.37}$$

$$L_{inches56} = 0.375$$

$$\alpha_{56} = \frac{k56}{\rho_{56} \cdot Cp56}$$

$$\mu_{56} = \rho_{56} \cdot \nu_{56}$$

$$k56 = k['Air', T=T_{film56}]$$

$$\rho_{56} = \rho['Air', T=T_{film56}, P=Patm56]$$

$$Patm56 = 1.01325$$

$$Cp56 = Cp['Air', T=T_{film56}]$$

$$\mu_{56} = Visc['Air', T=T_{film56}]$$

$$H_{over,L,ration56} = \frac{H_{inches56}}{L_{inches56}}$$

$$H_{inches56} = 65$$

$$H56 = \frac{H_{inches56}}{39.37}$$

$$Pr56 = \frac{\nu_{56}}{\alpha_{56}}$$

$$Nus_{56} = hbar56 \cdot \frac{L56}{k56}$$

$$q_{conv56} = hbar56 \cdot A_s \cdot [T_5 - T_6]$$

$$Nus_{56} = \left[1 + \left(\frac{0.0665 \cdot Ra_{L56}^{[1/3]}}{1 + \left[\frac{9000}{Ra_{L56}} \right]^{1.4}} \right)^2 \right]^{[1/2]}$$

$$q_{rad67} = A_s \cdot \sigma \cdot \left[\frac{T_6^4 - T_7^4}{\frac{1}{\epsilon_6} + \frac{1}{\epsilon_7} - 1} \right]$$

$$q_{rad67} + q_{conv67} = q_{total}$$

$$Ra_{L67} = g \cdot \beta_{67} \cdot [T_6 - T_7] \cdot \frac{L_{67}^3}{\alpha_{67} \cdot \nu_{67}}$$

$$\beta_{67} = \frac{1}{T_{film67}}$$

$$T_{film67} = \frac{T_6 + T_7}{2}$$

$$L_{67} = \frac{L_{inches12}}{39.37}$$

$$L_{inches67} = 0.375$$

$$\alpha_{67} = \frac{k_{67}}{\rho_{67} \cdot C_{p67}}$$

$$\mu_{67} = \rho_{67} \cdot \nu_{67}$$

$$k_{67} = k ['Air', T = T_{film67}]$$

$$\rho_{67} = \rho ['Air', T = T_{film67}, P = Patm67]$$

$$Patm67 = 1.01325$$

$$C_{p67} = Cp ['Air', T = T_{film67}]$$

$$\mu_{67} = Visc ['Air', T = T_{film67}]$$

$$H_{over,L,ration67} = \frac{H_{inches67}}{L_{inches67}}$$

$$H_{inches67} = 65$$

$$H_{67} = \frac{H_{inches67}}{39.37}$$

$$Pr_{67} = \frac{\nu_{67}}{\alpha_{67}}$$

$$\text{Nus}_{67} = \text{hbar}_{67} \cdot \frac{L_{67}}{k_{67}}$$

$$q_{\text{conv}67} = \text{hbar}_{67} \cdot A_s \cdot [T_6 - T_7]$$

$$\text{Nus}_{67} = \left[1 + \left(\frac{0.0665 \cdot \text{Ra}_{L67}^{1/3}}{1 + \left[\frac{9000}{\text{Ra}_{L67}} \right]^{1.4}} \right)^2 \right]^{1/2}$$

$$q_{\text{rad}78} = A_s \cdot \sigma \cdot \left[\frac{T_7^4 - T_8^4}{\frac{1}{\epsilon_7} + \frac{1}{\epsilon_8} - 1} \right]$$

$$q_{\text{rad}78} + q_{\text{conv}78} = q_{\text{total}}$$

$$\text{Ra}_{L78} = g \cdot \text{Beta}_{78} \cdot [T_7 - T_8] \cdot \frac{L_{78}^3}{\alpha_{78} \cdot \nu_{78}}$$

$$g = 9.8$$

$$\text{Beta}_{78} = \frac{1}{T_{\text{film}78}}$$

$$T_{\text{film}78} = \frac{T_7 + T_8}{2}$$

$$L_{78} = \frac{L_{\text{inches}78}}{39.37}$$

$$L_{\text{inches}78} = 3.125$$

$$\alpha_{78} = \frac{k_{78}}{\rho_{78} \cdot \text{Cp}_{78}}$$

$$\mu_{78} = \rho_{78} \cdot \nu_{78}$$

$$k_{78} = \mathbf{k} ['\text{Air}', T = T_{\text{film}78}]$$

$$\rho_{78} = \rho ['\text{Air}', T = T_{\text{film}78}, P = P_{\text{atm}78}]$$

$$P_{\text{atm}78} = 1.01325$$

$$\text{Cp}_{78} = \mathbf{Cp} ['\text{Air}', T = T_{\text{film}78}]$$

$$\mu_{78} = \mathbf{Visc} ['\text{Air}', T = T_{\text{film}78}]$$

$$H_{\text{over},L,\text{ration}78} = \frac{H_{\text{inches}78}}{L_{\text{inches}78}}$$

$$H_{\text{inches}78} = 65$$

$$H_{78} = \frac{H_{\text{inches}78}}{39.37}$$

$$\text{Pr}_{78} = \frac{\text{nu}_{78}}{\alpha_{78}}$$

$$\text{Nus}_{78} = \text{hbar}_{78} \cdot \frac{L_{78}}{k_{78}}$$

$$q_{\text{conv}_{78}} = \text{hbar}_{78} \cdot A_s \cdot [T_7 - T_8]$$

$$A_s = 4.132$$

$$\text{Nus}_{78} = 0.046 \cdot \text{Ra}_{L_{78}}^{[1/3]}$$

$$\text{Nus}_{78, \text{check, horizontal}} = 0.069 \cdot \text{Ra}_{L_{78}}^{[1/3]} \cdot \text{Pr}_{78}^{0.074}$$

$$\sigma = 5.67 \times 10^{-8}$$

$$\epsilon_1 = 1$$

$$\epsilon_2 = 0.1$$

$$\epsilon_3 = 0.1$$

$$\epsilon_4 = 0.1$$

$$\epsilon_5 = 0.1$$

$$\epsilon_6 = 0.1$$

$$\epsilon_7 = 0.1$$

$$\epsilon_8 = 1$$

$$T_1 = 922$$

$$T_8 = T \text{ ['Argon', P=8.7, x=0]}$$

SOLUTION

Unit Settings: [J]/[K]/[bar]/[kg]/[degrees]

$$\alpha_{12} = 0.0001423 \text{ [m}^2\text{/s]}$$

$$\alpha_{34} = 0.0001131 \text{ [m}^2\text{/s]}$$

$$\alpha_{56} = 0.00007037 \text{ [m}^2\text{/s]}$$

$$\alpha_{78} = 0.00001209 \text{ [m}^2\text{/s]}$$

$$\text{Beta}_{12} = 0.001108 \text{ [1/K]}$$

$$\text{Beta}_{34} = 0.001283 \text{ [1/K]}$$

$$\text{Beta}_{56} = 0.001719 \text{ [1/K]}$$

$$\text{Beta}_{78} = 0.004557 \text{ [1/K]}$$

$$\text{Cp}_{23} = 1110 \text{ [J/kg-K]}$$

$$\text{Cp}_{45} = 1073 \text{ [J/kg-K]}$$

$$\text{Cp}_{67} = 1016 \text{ [J/kg-K]}$$

$$\epsilon_1 = 1$$

$$\epsilon_3 = 0.1$$

$$\epsilon_5 = 0.1$$

$$\epsilon_7 = 0.1$$

$$\alpha_{23} = 0.0001298 \text{ [m}^2\text{/s]}$$

$$\alpha_{45} = 0.00009375 \text{ [m}^2\text{/s]}$$

$$\alpha_{67} = 0.00004032 \text{ [m}^2\text{/s]}$$

$$A_s = 4.132 \text{ [m}^2\text{]}$$

$$\text{Beta}_{23} = 0.001175 \text{ [1/K]}$$

$$\text{Beta}_{45} = 0.001444 \text{ [1/K]}$$

$$\text{Beta}_{67} = 0.002373 \text{ [1/K]}$$

$$\text{Cp}_{12} = 1121 \text{ [J/kg-K]}$$

$$\text{Cp}_{34} = 1094 \text{ [J/kg-K]}$$

$$\text{Cp}_{56} = 1047 \text{ [J/kg-K]}$$

$$\text{Cp}_{78} = 1002 \text{ [J/kg-K]}$$

$$\epsilon_2 = 0.1$$

$$\epsilon_4 = 0.1$$

$$\epsilon_6 = 0.1$$

$$\epsilon_8 = 1$$

```

g = 9.8 [m/s2]
H23 = 1.651 [m]
H45 = 1.651 [m]
H67 = 1.651 [m]
hbar12 = 6.552 [W/*m2 * K]
hbar34 = 5.884 [W/*m2 * K]
hbar56 = 4.693 [W/*m2 * K]
hbar78 = 3.959 [W/*m2 * K]
Hinches23 = 65 [in]
Hinches45 = 65 [in]
Hinches67 = 65 [in]
Hover,L,ration12 = 173.3 [ ]
Hover,L,ration34 = 173.3 [ ]
Hover,L,ration56 = 173.3 [ ]
Hover,L,ration78 = 20.8 [ ]
k23 = 0.05979 [W/m-K]
k45 = 0.05126 [W/m-K]
k67 = 0.03431 [W/m-K]
L12 = 0.009525 [m]
L34 = 0.009525 [m]
L56 = 0.009525 [m]
L78 = 0.07938 [m]
Lgap,inches = 0.375 [in]
Linches23 = 0.375 [in]
Linches45 = 0.375 [in]
Linches67 = 0.375 [in]
mu12 = 0.00003926 [kg/m-s]
mu34 = 0.00003581 [kg/m-s]
mu56 = 0.00002963 [kg/m-s]
mu78 = 0.00001454 [kg/m-s]
nu23 = 0.00009119 [m2/s]
nu45 = 0.00006517 [m2/s]
nu67 = 0.00002839 [m2/s]
Nus12 = 1
Nus23 = 1
Nus45 = 1
Nus67 = 1.021
Nus78,check,horizontal = 23.66 [K0.3333]
Patm23 = 1.013 [bar]
Patm45 = 1.013 [bar]
Patm67 = 1.013 [bar]
Pr12 = 0.7054
Pr34 = 0.6987
Pr56 = 0.6937
Pr78 = 0.7474
qconv23 = 1702 [W]
qconv45 = 2124 [W]
qconv67 = 2943 [W]
qrad12 = 2654.795 [W]
qrad34 = 1813 [W]
qrad56 = 1243 [W]
qrad78 = 256.1 [W]
RaL12 = 25.26
RaL34 = 94.22
RaL56 = 536.4
RaL78 = 4.300E+07 [K]
H12 = 1.651 [m]
H34 = 1.651 [m]
H56 = 1.651 [m]
H78 = 1.651 [m]
hbar23 = 6.278 [W/*m2 * K]
hbar45 = 5.382 [W/*m2 * K]
hbar67 = 3.676 [W/*m2 * K]
Hinches12 = 65 [in]
Hinches34 = 65 [in]
Hinches56 = 65 [in]
Hinches78 = 65 [in]
Hover,L,ration23 = 173.3 [ ]
Hover,L,ration45 = 173.3 [ ]
Hover,L,ration67 = 173.3 [ ]
k12 = 0.06241 [W/m-K]
k34 = 0.05605 [W/m-K]
k56 = 0.0447 [W/m-K]
k78 = 0.0195 [W/m-K]
L23 = 0.009525 [m]
L45 = 0.009525 [m]
L67 = 0.009525 [m]
Lgap = 0.009525 [m]
Linches12 = 0.375 [in]
Linches34 = 0.375 [in]
Linches56 = 0.375 [in]
Linches78 = 3.125 [in]
mu23 = 0.00003784 [kg/m-s]
mu45 = 0.00003321 [kg/m-s]
mu67 = 0.00002378 [kg/m-s]
nu12 = 0.0001004 [m2/s]
nu34 = 0.00007903 [m2/s]
nu56 = 0.00004881 [m2/s]
nu78 = 0.000009036 [m2/s]
Nus12,check,horizontal = 0.1973
Nus34 = 1
Nus56 = 1
Nus78 = 16.12 [ ]
Patm12 = 1.013 [bar]
Patm34 = 1.013 [bar]
Patm56 = 1.013 [bar]
Patm78 = 1.013 [bar]
Pr23 = 0.7024
Pr45 = 0.6951
Pr67 = 0.7042
qconv12 = 1042 [W]
qconv34 = 1884 [W]
qconv56 = 2454 [W]
qconv78 = 3441 [W]
qrad23 = 1995 [W]
qrad45 = 1573 [W]
qrad67 = 753.3 [W]
Qtotal = 3696.784 [W]
RaL23 = 55.17
RaL45 = 191.1
RaL67 = 3401
rho12 = 0.391 [kg/m3]

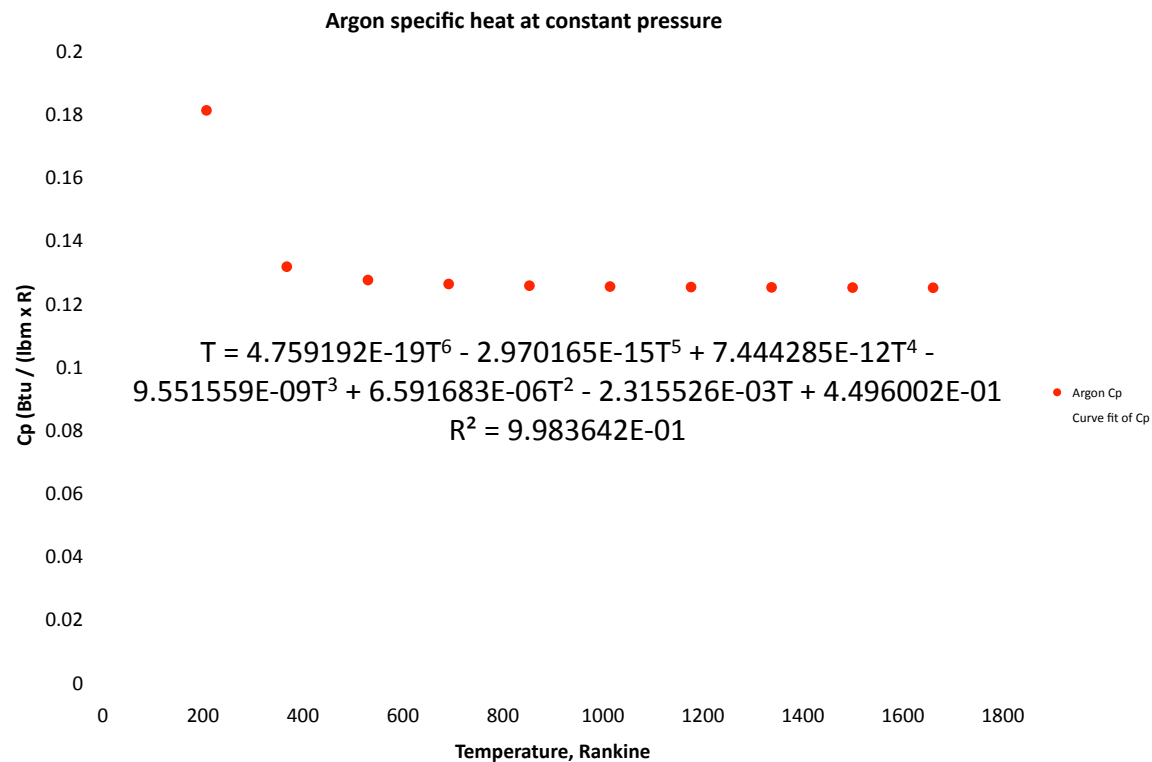
```

$\rho_{23} = 0.415 \text{ [kg/m}^3\text{]}$	$\rho_{34} = 0.4531 \text{ [kg/m}^3\text{]}$
$\rho_{45} = 0.5096 \text{ [kg/m}^3\text{]}$	$\rho_{56} = 0.6069 \text{ [kg/m}^3\text{]}$
$\rho_{67} = 0.8376 \text{ [kg/m}^3\text{]}$	$\rho_{78} = 1.609 \text{ [kg/m}^3\text{]}$
$\sigma = 5.670\text{E-}08 \text{ [W / (m}^2 \cdot \text{K}^4\text{)]}$	$T_1 = 922 \text{ [K]}$
$T_2 = 883.513 \text{ [K]}$	$T_3 = 817.9 \text{ [K]}$
$T_4 = 740.4 \text{ [K]}$	$T_5 = 644.9 \text{ [K]}$
$T_6 = 518.4 \text{ [K]}$	$T_7 = 324.592171 \text{ [K]}$
$T_8 = 114.2584 \text{ [K]}$	$T_{\text{film}12} = 902.8 \text{ [K]}$
$T_{\text{film}23} = 850.7 \text{ [K]}$	$T_{\text{film}34} = 779.2 \text{ [K]}$
$T_{\text{film}45} = 692.7 \text{ [K]}$	$T_{\text{film}56} = 581.6 \text{ [K]}$
$T_{\text{film}67} = 421.5 \text{ [K]}$	$T_{\text{film}78} = 219.4 \text{ [K]}$

39 potential unit problems were detected.

EES suggested units (shown in purple) for Nus_78_check_horizontal .

Temperature (°R)	Pressure (psia)	Cp (Btu/lbm-°R)
207	126.2	0.18071
367.6	126.2	0.13121
529.9	126.2	0.12698
691.3	126.2	0.12573
852.8	126.2	0.1252
1014	126.2	0.12492
1176	126.2	0.12476
1337	126.2	0.12466
1499	126.2	0.12459
1660	126.2	0.12454



$$Cp_{average} = \frac{1}{1660 - 205.7} \int_{205.7}^{1660} (4.759192E-19T^6 - 2.970165E-15T^5 + 7.444285E-12T^4 - 9.551559E-09T^3 + 6.591683E-06T^2 - 2.315526E-03T + 4.496002E-01) dT = 0.1282 \frac{\text{Btu}}{\text{lbm x } ^\circ\text{R}}$$

{This sheet calculates the inlet pressure drop for the LAPD filter vessel relief valve}

{CGA 6.1.4 c) used }

$$P_i = P - (3.36E-6) * I * (W^2) * v / (d^5) \quad \{psia\}$$

{pressure drop thru the relief valve inlet piping}

$$\Delta P = P - P_i \quad \{psid\}$$

{mass flow rate calculated from 6.1.4 a) }

$$W = 419.5 \quad \{lbm/hr\}$$

{average temperature between the flow rated saturation temperature and the inlet temperature of the valve calculated with 6.1.4 b) }

$$T_{average} = (T_i + T_s) / 2 \quad \{R\}$$

{6.1.4 b temperature at the inlet of the relief valve}

$$T_i = 2145 - (2145 - T_s) / \exp \left(\left(5.24 * 1.315 * (L_{cap}) / (W * C_p) \right) \right) \quad \{R\}$$

{Average specific heat btu/lbm-R at constant pressure between Ts and 1660 R}

$$C_p = 0.1281 \quad \{btu/lbm-R\}$$

{linear length of pipe to the inlet of the relief valve}

$$L_{cap} = 6 \quad \{ft\}$$

$$L_{ft} = L_{cap} \quad \{ft\}$$

{Saturation temperature deg. R at the flow rating pressure}

$$T_s = \text{Temperature}(\text{Argon}, P=P, x=1) \quad \{R\}$$

{Specific volume of the fluid being relieved in ft^3/lb at the flow rating pressure and the average temperature between Ti and Ts}

$$v = \text{Volume}(\text{Argon}, T=T_{average}, P=P) \quad \{ft^3/lb\}$$

{Specific volume of the fluid being relieved in ft^3/lb at the relief valve inlet pressure and temperature}

$$v_i = \text{Volume}(\text{Argon}, T=T_i, P=P_i) \quad \{ft^3/lb\}$$

{CGA correction factor}

$$F_{CGA} = \sqrt{(P_i * v_i) / (P * v_{CGA})}$$

{Specific volume of the fluid being relieved in ft^3/lb at the flow rating pressure and the saturation temperature }

$$v_{CGA} = \text{Volume}(\text{Argon}, x=1, P=P) \quad \{ft^3/lb\}$$

{psia, flow rating pressure}

$$P = 126.2 \quad \{psia\}$$

{internal diameter of the piping leading up to the relief valve}

$$d = 1.097 \quad \{inches\}$$

$$D_{ft} = d / 12 \quad \{feet\}$$

{friction factor used in 6.1.4 c, set equal to friction factor calculated by the Colebrook equation}

$$f = f_{ci} \quad \{dimensionless\}$$

$$\{l = 6\}$$

{Resistance coefficients from Crane 410 }

$$K = \text{num_elbows} * 20 * f_{ci} \quad \{elbows\} + \text{num_tee_diverg_branch} * 0.64 \quad \{tees\} + f * L_{ft} / D_{ft} \quad \{straight\ pipe\} + 0.78 \quad \{inward\ projecting\ inlet\}$$

{K is unitless}

{calculate the equivalent length l that includes the tees, elbows, and inlet between the vessel and relief valve piping}

$$K = f \cdot l / D_{ft}$$

$$\text{num_elbows} = 4 \quad \{\text{number of elbows in the path from the vessel to the relief valve}\}$$

$$\text{num_tee_diverg_branch} = 2 \quad \{\text{number of tees in the path from the vessel to the relief valve, these are diverging flow thru branch tees}\}$$

{Colebrook equation for the turbulent friction factor, Crane 410 equation 1-20, set Reynolds number to 1E8 to get a fully turbulent friction factor f_T }

$$1/\text{SQRT}(f_T) = -2.0 \cdot \log_{10}(\epsilon / (3.7 \cdot D_{ft}) + 2.51 / (\text{Re}_f \cdot \text{SQRT}(f_T)))$$

$$\text{Re}_f = 1\text{E}8 \quad \{\text{A large Reynolds number is input to get the fully turbulent friction factor}\}$$

{Reynolds # for friction factor f in 6.1.4 c}

$$\text{Re} = 6.315 \cdot W / (d \cdot \mu) \quad \{\text{dimensionless}\}$$

{absolute (dynamic) viscosity in centipoise }

$$\mu = \text{Viscosity}(\text{Argon}, T = T_{\text{average}}, P = P) / 2.42 \quad \{\text{cp, converted from lb/ft-hr by dividing by 2.42}\}$$

{Colebrook equation which offers an implicit iterative solution for the turbulent friction factor}

$$1/\text{SQRT}(f_{ci}) = -2.0 \cdot \log_{10}(\epsilon / (3.7 \cdot D_{ft}) + 2.51 / (\text{Re} \cdot \text{SQRT}(f_{ci}))) \quad \{\text{dimensionless}\}$$

{absolute roughness in feet for drawn tubing = 0.000,005, for commercial steel = 0.00015}

$$\epsilon = 0.00015$$

$$P_i = P - 0.00000336 \cdot f \cdot l \cdot W^2 \cdot \frac{v}{d^5}$$

$$\Delta P = P - P_i$$

$$W = 419.5$$

$$T_{\text{average}} = \frac{T_i + T_s}{2}$$

$$T_i = 2145 - \left[\frac{2145 - T_s}{\exp\left(5.24 \cdot 1.315 \cdot \frac{L_{\text{cap}}}{W \cdot C_p}\right)} \right]$$

$$C_p = 0.1281$$

$$L_{\text{cap}} = 6$$

$$L_{\text{ft}} = L_{\text{cap}}$$

$$T_s = T \left[\text{'Argon'}, P = P, x = 1 \right]$$

$$v = v \left[\text{'Argon'}, T = T_{\text{average}}, P = P \right]$$

$$v_i = v \left[\text{'Argon'}, T = T_i, P = P_i \right]$$

$$F_{CGA} = \sqrt{\frac{P_i \cdot v_i}{P \cdot v_{CGA}}}$$

$$v_{CGA} = v \left[\text{'Argon'}, x=1, P=P \right]$$

$$P = 126.2$$

$$d = 1.097$$

$$D_{ft} = \frac{d}{12}$$

$$f = f_{ci}$$

$$K = \text{num}_{\text{elbows}} \cdot 20 \cdot f_T + \text{num}_{\text{tee,diverg,branch}} \cdot 0.64 + f \cdot \frac{L_{ft}}{D_{ft}} + 0.78$$

$$K = f \cdot \frac{L}{D_{ft}}$$

$$\text{num}_{\text{elbows}} = 4$$

$$\text{num}_{\text{tee,diverg,branch}} = 2$$

$$\frac{1}{\sqrt{f_T}} = -2 \cdot \log \left[\frac{\varepsilon}{3.7 \cdot D_{ft}} + \frac{2.51}{\text{Re}_{f,T} \cdot \sqrt{f_T}} \right]$$

$$\text{Re}_{f,T} = 1 \times 10^8$$

$$\text{Re} = 6.315 \cdot \frac{W}{d \cdot \mu}$$

$$\mu = \frac{\text{Visc} \left[\text{'Argon'}, T=T_{\text{average}}, P=P \right]}{2.42}$$

$$\frac{1}{\sqrt{f_{ci}}} = -2 \cdot \log \left[\frac{\varepsilon}{3.7 \cdot D_{ft}} + \frac{2.51}{\text{Re} \cdot \sqrt{f_{ci}}} \right]$$

$$\varepsilon = 0.00015$$

SOLUTION

Unit Settings: [R]/[psia]/[lbm]/[degrees]

$$C_p = 0.1281 \text{ [btu/lbm-R]}$$

$$\Delta P = 0.2865 \text{ [psid]}$$

$$\varepsilon = 0.00015$$

$$F_{CGA} = 2.687 \text{ [ft}^{1.5}/\text{lb}_m^{0.5}]$$

$$f_T = 0.02224$$

$$L = 20.34 \text{ [ft]}$$

$$L_{ft} = 6 \text{ [ft]}$$

$$\text{num}_{\text{elbows}} = 4$$

$$P = 126.2000$$

$$\text{Re} = 83335$$

$$d = 1.097 \text{ [in]}$$

$$D_{ft} = 0.09142 \text{ [ft]}$$

$$f = 0.02447$$

$$f_{ci} = 0.02447$$

$$K = 5.445$$

$$L_{cap} = 6 \text{ [ft]}$$

$$\mu = 0.02897819 \text{ [cp]}$$

$$\text{num}_{\text{tee,diverg,branch}} = 2$$

$$P_i = 125.913548$$

$$\text{Re}_{f,T} = 1.000\text{E}+08$$

$$T_{\text{average}} = 726.1 \text{ [R]}$$

$$T_s = 205.7 \text{ [R]}$$

$$v_{\text{CGA}} = 0.3685 \text{ [ft}^3/\text{lb}_m\text{]}$$

$$W = 419.50000 \text{ [lb/hr]}$$

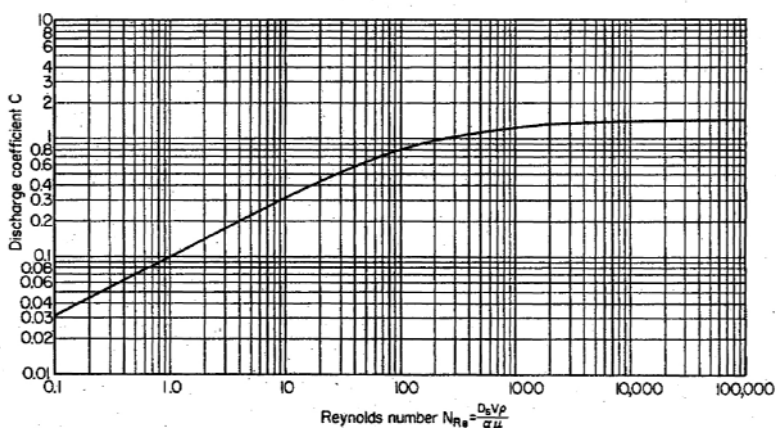
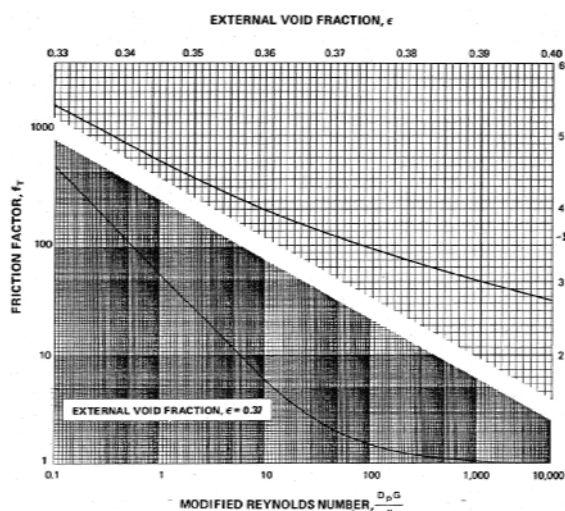
$$T_i = 1246 \text{ [R]}$$

$$v = 1.546 \text{ [ft}^3/\text{lb}_m\text{]}$$

$$v_i = 2.666 \text{ [ft}^3/\text{lb}_m\text{]}$$

8 potential unit problems were detected.

EES suggested units (shown in purple) for F_{CGA} T_s v v_{CGA} v_i .



{-----}

{Filter bed pressure drop for LAPD - both filters during a relief valve event}

{Assume vapor travels thru the entire bed}

{units of F, psia}

$G = W / A_{\text{filter}}$ {lb/(hr*ft²) superficial mass velocity for filter bed pressure drop calculation}

$A_{\text{filter}} = (PI/4)*(12.39/12)^2$ {ft² cross sectional area of filter, 12 inch SCH 10 pipe}

$L_{\text{filter}} = 40/12$ {ft, length of filter bed, see drawing 466500 }

{Ergun equation for the calculation of pressure drop in adsorbent beds from Union Carbide Fixed-Bed Pressure Drop Calculations, the beds have different diameter beads}

$ft_{\text{filter_O2}} * Ct_{\text{O2}} * (G^2) * L_{\text{filter}} / (\rho_{\text{GAR}} * Dp_{\text{oxygen}}) = dP_{\text{filter_O2}}$ {oxygen filter bed pressure drop psi}

$ft_{\text{filter_MS}} * Ct_{\text{MS}} * (G^2) * L_{\text{filter}} / (\rho_{\text{GAR}} * Dp_{\text{molecular}}) = dP_{\text{filter_MS}}$ {molecular sieve filter bed pressure drop psi}

$Dp_{\text{molecular}} = 0.00666$ {ft, average diameter of molecular sieve particles, 8 x 12 mesh, 8 mesh = 0.0937 inches = 0.00781 ft, 12 mesh = 0.0661 inches = 0.00551 ft, average = 0.08 inches = 0.00666 ft}

$Dp_{\text{oxygen}} = 0.00336$ {ft, average diameter of oxygen filter particles 14x28 mesh, 14 mesh = 0.0555 inches, 28 mesh = 0.02512 inches, average = 0.0403 inches = 0.003359 feet }

{pressure drop coefficient (ft)(sq hr)/(sq in), determine from graph which has Ct plotted as a function of external void fraction, 3.6E-10 for the 0.37 void fraction Union Carbide reference suggests for mole sieve}

$Ct_{\text{O2}} = 3.6E-10$

$Ct_{\text{MS}} = 3.6E-10$

{friction factor based on modified Reynolds #, get from graph}

$ft_{\text{filter_O2}} = \text{INTERPOLATE}('ft', \text{Column1}', \text{Column2}', \text{Column1} = Re_{\text{oxygen}})$ {look up data from digitized plot in table}

$ft_{\text{filter_MS}} = \text{INTERPOLATE}('ft', \text{Column1}', \text{Column2}', \text{Column1} = Re_{\text{molecular}})$ {look up data from digitized plot in table}

$Re_{\text{molecular}} = Dp_{\text{molecular}} * G / \mu$ {Reynolds number for molecular sieve}

$Re_{\text{oxygen}} = Dp_{\text{oxygen}} * G / \mu$ {Reynolds number for oxygen filter}

$\mu = \text{VISCOSITY}(\text{Argon}, T = T_{\text{vent}}, P = P_{\text{GAR}})$ {argon viscosity at flowing conditions lb/hr-ft}

$\rho_{\text{GAR}} = \text{Density}(\text{Argon}, T = T_{\text{vent}}, P = P_{\text{GAR}})$ {density of argon gas at flowing conditions in the filter, lb/ft³}

$T_{\text{vent}} = 80.3$ {temperature of the venting gas, F, the gas would be cold because it originates from vaporized liquid such that

room temperature is conservative}

$P_GAR = 126.2$ *{relief valve flow rating pressure psia}*

$\rho_{stp} = \text{Density}(\text{Argon}, T=70, P=14.7)$ *{density @ std conditions for SCFH calc}*

$W = GAR_SCFH * \rho_{stp}$ *{relate mass flow to SCFH}*

$W = 419.5$ *{venting argon mass flow rate lbm/hr, from relief valve calcs, fire case}*

{-----}

{Filter screen pressure drop for LAPD filter during a relief event}

{LAPD top filter screen is FNAL drawing # 489456}

{Using ImageJ software the slot open area is 32 in², these slots are then filled with 2 screens}

{Screen 1 McMaster #85385T425 60x60 mesh, 0.0075" wire diameter, 0.009" opening width, 30.5% open area}

{Screen 2 McMaster #85385T369 8x8 mesh, 0.035" wire diameter, 0.09" opening width, 51.8% open area}

{Screen pressure drop reference is the Chemical Engineers Handbook by Perry and Chilton, 5th Edition, page 5-37}

{The flow thru a screen can be considered as flow thru a number of orifices or nozzles in parallel.

Thus the pressure drop or head loss across a screen can be computed from an orifice type equation}

{Experimental data indicates that for a series of screens the over-all head loss is directly proportional to the number of screens in series

and is not affected by either the spacing between successive screens or by their orientation with respect to one another}

{For the filter screens the pressure drop is computed across each screen}

$\Delta h_1 = (n/C_1^2) * ((1 - \alpha_1^2) / \alpha_1^2) * (V^2 / (2 * g_c))$ *{screen 1 head loss in ft of flowing liquid, equation 5-100}*

$\Delta P_{screen_1} = \Delta h_1 * \rho_{GAR} / 144$ *{convert screen 1 head loss from feet to psi}*

$\Delta h_2 = (n/C_2^2) * ((1 - \alpha_2^2) / \alpha_2^2) * (V^2 / (2 * g_c))$ *{screen 2 head loss in ft of flowing liquid, equation 5-100}*

$\Delta P_{screen_2} = \Delta h_2 * \rho_{GAR} / 144$ *{convert screen 2 head loss from feet to psi}*

$n = 1$ *{number of screens in series, dimensionless, each screen is computed individually since the screens are different sizes}*

$C_1 = \text{INTERPOLATE}('cs', 'Column1', 'Column2', Column1=N_Re_1)$ *{screen 1 discharge coefficient, dimensionless, function of the Reynolds number see Figure 5-44}*

$C_2 = \text{INTERPOLATE}('cs', 'Column1', 'Column2', Column1=N_Re_2)$ *{screen 2 discharge coefficient, dimensionless, function of the Reynolds number see Figure 5-44}*

$\alpha_1 = 0.305$ *{fractional free projected area of screen 1, dimensionless}*

$\alpha_2 = 0.518$ *{fractional free projected area of screen 2, dimensionless}*

$V = W / (\rho * 3600 * A_{screen})$ *{superficial velocity ahead of the screen, ft/sec}*

$A_{screen} = 32 / 144$ *{flow has to go thru slots, estimate upstream area as the slot area of 32 in² and convert to ft²}*

$g_c = 32.17$ *{dimensional constant, 32.17 (lb.)/(ft.)/(lb. force)(sec²) }*

$N_Re_1 = D_{s_1} * V * \rho / (\alpha_1 * \mu_{screen})$ *{Screen 1 reynolds number }*

$N_Re_2 = D_{s_2} * V * \rho / (\alpha_2 * \mu_{screen})$ *{Screen 2 reynolds number }*

$D_{s_1} = 0.009 / 12$ *{aperture width screen 1, feet}*

$D_{s_2} = 0.09 / 12$ *{aperture width screen 2, feet}*

$\rho = \rho_{GAR}$ *{fluid denisty at flowing conditions, lb/ft³}*

$\mu_{screen} = \text{VISCOSITY}(\text{Argon}, T=T_{vent}, P=P_{GAR}) / 3600$ *{fluid viscosity at flowing conditions lb./((ft.)(sec.)), converted from EES lb/hr-ft units}*

{-----}

$$G = \frac{W}{A_{\text{filter}}}$$

$$A_{\text{filter}} = \frac{\pi}{4} \cdot \left[\frac{12.39}{12} \right]^2$$

$$L_{\text{filter}} = \frac{40}{12}$$

$$f_{\text{filter,O2}} \cdot Ct_{\text{O2}} \cdot G^2 \cdot \frac{L_{\text{filter}}}{\rho_{\text{GAr}} \cdot Dp_{\text{oxygen}}} = dP_{\text{filter,O2}}$$

$$f_{\text{filter,MS}} \cdot Ct_{\text{MS}} \cdot G^2 \cdot \frac{L_{\text{filter}}}{\rho_{\text{GAr}} \cdot Dp_{\text{molecular}}} = dP_{\text{filter,MS}}$$

$$Dp_{\text{molecular}} = 0.00666$$

$$Dp_{\text{oxygen}} = 0.00336$$

$$Ct_{\text{O2}} = 3.6 \times 10^{-10}$$

$$Ct_{\text{MS}} = 3.6 \times 10^{-10}$$

$$f_{\text{filter,O2}} = \text{Interpolate} \left['ft', 'Column1', 'Column2', 'Column1' = Re_{\text{oxygen}} \right]$$

$$f_{\text{filter,MS}} = \text{Interpolate} \left['ft', 'Column1', 'Column2', 'Column1' = Re_{\text{molecular}} \right]$$

$$Re_{\text{molecular}} = Dp_{\text{molecular}} \cdot \frac{G}{\mu}$$

$$Re_{\text{oxygen}} = Dp_{\text{oxygen}} \cdot \frac{G}{\mu}$$

$$\mu = \text{Visc} \left['Argon', T = T_{\text{vent}}, P = P_{\text{GAr}} \right]$$

$$\rho_{\text{GAr}} = \rho \left['Argon', T = T_{\text{vent}}, P = P_{\text{GAr}} \right]$$

$$T_{\text{vent}} = 80.3$$

$$P_{\text{GAr}} = 126.2$$

$$\rho_{\text{stp}} = \rho \left['Argon', T = 70, P = 14.7 \right]$$

$$W = GAr_{\text{SCFH}} \cdot \rho_{\text{stp}}$$

$$W = 419.5$$

$$\Delta h_1 = \frac{n}{C_1^2} \cdot \left[\frac{1 - \alpha_1^2}{\alpha_1^2} \right] \cdot \frac{V^2}{2 \cdot g_c}$$

$$\Delta P_{\text{screen},1} = \Delta h_{1,1} \cdot \frac{\rho_{\text{GAr}}}{144}$$

$$\Delta h_{2,2} = \frac{n}{C_2^2} \cdot \left[\frac{1 - \alpha_2^2}{\alpha_2^2} \right] \cdot \frac{V^2}{2 \cdot g_c}$$

$$\Delta P_{\text{screen},2} = \Delta h_{2,2} \cdot \frac{\rho_{\text{GAr}}}{144}$$

$$n = 1$$

$$C_1 = \text{Interpolate} \left[\text{'cs'}, \text{'Column1'}, \text{'Column2'}, \text{'Column1'} = N_{\text{Re},1} \right]$$

$$C_2 = \text{Interpolate} \left[\text{'cs'}, \text{'Column1'}, \text{'Column2'}, \text{'Column1'} = N_{\text{Re},2} \right]$$

$$\alpha_1 = 0.305$$

$$\alpha_2 = 0.518$$

$$V = \frac{W}{\rho \cdot 3600 \cdot A_{\text{screen}}}$$

$$A_{\text{screen}} = \frac{32}{144}$$

$$g_c = 32.17$$

$$N_{\text{Re},1} = D_{s,1} \cdot V \cdot \frac{\rho}{\alpha_1 \cdot \mu_{\text{screen}}}$$

$$N_{\text{Re},2} = D_{s,2} \cdot V \cdot \frac{\rho}{\alpha_2 \cdot \mu_{\text{screen}}}$$

$$D_{s,1} = \frac{0.009}{12}$$

$$D_{s,2} = \frac{0.09}{12}$$

$$\rho = \rho_{\text{GAr}}$$

$$\mu_{\text{screen}} = \frac{\text{Visc} \left[\text{'Argon'}, T = T_{\text{vent}}, P = P_{\text{GAr}} \right]}{3600}$$

SOLUTION

Unit Settings: [F]/[psia]/[lbm]/[degrees]

$$\alpha_1 = 0.305$$

$$A_{\text{filter}} = 0.8373 \text{ [ft}^2\text{]}$$

$$C_{\text{tMS}} = 3.600\text{E-}10 \text{ [ft}^3\text{hr}^2\text{/in}^2\text{]}$$

$$C_1 = 0.7852$$

$$\Delta P_{\text{screen},1} = 0.0005369 \text{ [lbm/in}^2\text{]}$$

$$\Delta h_{1,1} = 0.08846 \text{ [ft]}$$

$$dP_{\text{filter,MS}} = 0.09197 \text{ [lb}_m\text{/in}^2\text{]}$$

$$D_{\text{pmolecular}} = 0.00666 \text{ [ft]}$$

$$D_{s,1} = 0.00075 \text{ [ft]}$$

$$ft_{\text{filter,MS}} = 1.777$$

$$\alpha_2 = 0.518$$

$$A_{\text{screen}} = 0.2222 \text{ [ft}^2\text{]}$$

$$C_{\text{tO2}} = 3.600\text{E-}10 \text{ [ft}^3\text{hr}^2\text{/in}^2\text{]}$$

$$C_2 = 1.155$$

$$\Delta P_{\text{screen},2} = 0.0000694 \text{ [lbm/in}^2\text{]}$$

$$\Delta h_{2,2} = 0.01143 \text{ [ft]}$$

$$dP_{\text{filter,O2}} = 0.2614 \text{ [lb}_m\text{/in}^2\text{]}$$

$$D_{\text{poxygen}} = 0.00336 \text{ [ft]}$$

$$D_{s,2} = 0.0075 \text{ [ft]}$$

$$ft_{\text{filter,O2}} = 2.549$$

$G = 501.028 \text{ [lb}_m\text{/hr-ft}^2\text{]}$
 $g_c = 32.17 \text{ [lbm-ft/lbm-sec}^2\text{]}$
 $\mu = 0.05534 \text{ [lb}_m\text{/ft-hr]}$
 $n = 1$
 $N_{Re,2} = 493.9$
 $Re_{molecular} = 60.3$
 $\rho = 0.874 \text{ [lb}_m\text{/ft}^3\text{]}$
 $\rho_{stp} = 0.1034 \text{ [lb}_m\text{/ft}^3\text{]}$
 $V = 0.5999 \text{ [ft/sec]}$

$G_{ArSCFH} = 4058 \text{ [ft}^3\text{/hr]}$
 $L_{filter} = 3.333 \text{ [ft]}$
 $\mu_{screen} = 0.00001537 \text{ [lb}_m\text{/ft-sec]}$
 $N_{Re,1} = 83.88$
 $P_{GAr} = 126.2 \text{ [psia]}$
 $Re_{oxygen} = 30.42$
 $\rho_{GAr} = 0.874 \text{ [lb}_m\text{/ft}^3\text{]}$
 $T_{vent} = 80.3 \text{ [F]}$
 $W = 419.5 \text{ [lb}_m\text{/hr]}$

4 potential unit problems were detected.

Lookup Table: ft

	Column1	Column2
Row 1	0.5761	100.6
Row 2	0.7349	78.51
Row 3	1.042	54.66
Row 4	1.417	40.49
Row 5	1.988	29.07
Row 6	2.618	22.21
Row 7	4.084	14.53
Row 8	5.853	10.12
Row 9	7.387	7.892
Row 10	9.424	6.093
Row 11	12.28	4.953
Row 12	15.5	4.111
Row 13	19.78	3.412
Row 14	25.78	2.831
Row 15	33.24	2.424
Row 16	44.25	2.032
Row 17	58.91	1.794
Row 18	78.44	1.617
Row 19	106.7	1.473
Row 20	139.1	1.355
Row 21	187.1	1.26
Row 22	260	1.183
Row 23	342.5	1.135
Row 24	496.5	1.077
Row 25	654.3	1.076
Row 26	899.4	1.042
Row 27	1277	1.02

Lookup Table: cs

	Column1	Column2
Row 1	0.0986	0.0316
Row 2	0.1969	0.0447
Row 3	0.2944	0.0553
Row 4	0.3971	0.0637
Row 5	0.4932	0.072
Row 6	0.6932	0.083
Row 7	0.9845	0.1007
Row 8	1.945	0.1408
Row 9	2.909	0.1725
Row 10	3.923	0.2009
Row 11	5.928	0.2461
Row 12	9.828	0.3109

Lookup Table: cs

	Column1	Column2
Row 13	19.62	0.4392
Row 14	39.17	0.5899
Row 15	68.39	0.7378
Row 16	99.18	0.8171
Row 17	198.1	0.982
Row 18	387.6	1.122
Row 19	592	1.17
Row 20	971.9	1.257
Row 21	1942	1.366
Row 22	3801	1.382
Row 23	9833	1.429
Row 24	19445	1.476
Row 25	38857	1.494
Row 26	95475	1.498